High Speed Tool Steel
On Lathe Work

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HIGH SPEED TOOL STEEL

ON

LATHE WORK

A THESIS

PRESENTED BY

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H.M. Raymond Dean of Eng. Studies

HIGH SPEED TOOL STEEL ON LATHE WORK.

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First: To run brake tests on the lathe with a view to determining the efficiency of the lathe under a variety of loads, and speeds. To calibrate the lathe so that any desired number of revolutions per minute of the spindle may be secured by referring to the tables accompanying this thesis.

Second: To conduct a series of tests of high speed tool steel on cast iron, using six different standard grades of steel, determining the capacity of each grade of steel, the maximum amount of stock that can be removed in a given time using certain depths of cut and cutting speeds, without breaking down the tool.

Third: To fit up a drill press for the purpose of making comparative hardness tests on the cast iron specimens used in the tests.

PRELIMINARY DISCUSSION

Cast iron is extensively used in engineering work because of its low first cost, its strength, and the facility with which it can be cast into any desired form. The great variety of machine parts made from cast iron, and brought to the desired shape in lathes, by means of some form of tool steel, tends to make the subject of this thesis of interest to the commercial world.

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During the last five years a new material known as "high speed tool steel" has been revolutionising modern machine shop practice. This steel may be used for any shape or form of tool, and gives a very large material increase of output and saving of time in machin-

ing ,with a durability of from five to thirty times that of the best crucible cast steels. By means of this "high speed steel", steel bars can be machined and turned at a maximum speed of 500 feet per minute,and cast iron drilled at the rate of 25 inches per minute. The cutting speeds of the ordinary carbon crucible steels are usually from 30 to 50 feet per minute.

In the manufacture of"high speed steel" it is necessary to use the purest quality of iron and alloys. The steel is made by various steel companies,each company having its own method and composition for making its special grade. The combinations usually used are iron and carbon with (1) tungsten and chromium,(2)molybdenum and chromium,(3)tungsten,molybdenum,and chromium. Each one of these metals has its influence on the quality of the steel.

The main requirements of a good "high speed steel"demand that it should withstand the very high temperature due to friction when cutting at a high speed. In our own tests we have noted on several occasions that certain of the steels used were able to cut off stock without failing when the nose of the tool was at a red heat. "High speed tools"are hardened in air,in a cold air blast,or in oil. The "high speed steel"can be used for lathe tools,planer tools, taps,milling cutters,reamers,formed cutters,twist drills,undercut tools,boiler punches,drawing dies,pneumatic chisels,and pneumatic riveters.

When annealed the steel is soft and can be forged and machined as easily as ordinary carbon steel. The unannealed steel is glass hard.

ing, with a durability of from five to thirty times that of the best crucible cast steels. By means of this "high speed steel", steel bars can be machined and turned at a maximum speed of 100 feet per minute, and cast iron drilled at the rate of 25 inches per minute. The cutting speeds of the ordinary carbon crucible steels are usually from 20 to 40 feet per minute.

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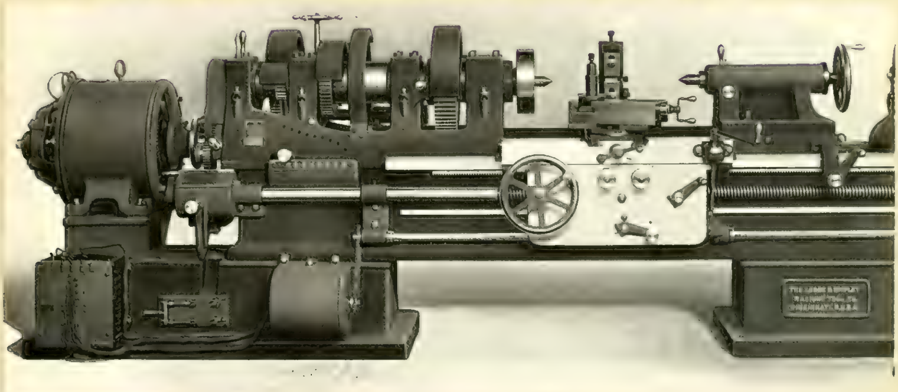
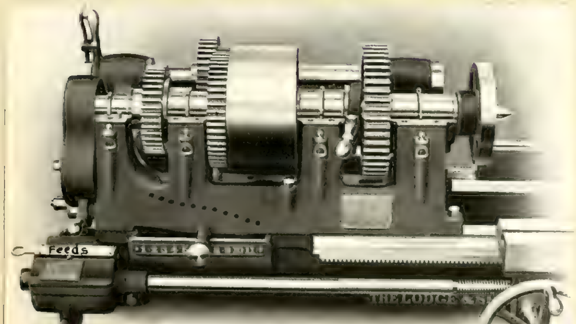
When annealed the steel is soft and can be forged, and machined easily as ordinary carbon steel. The unannealed steel is glass hard.

DESCRIPTION OF THE LATHE

The tests were all made on a Lodge and Shipley 16" patent head high speed lathe, of the latest pattern. The lathe is directly connected to a Northern variable speed motor of 2 1/2 rated electrical horse power. This motor takes its power from leads connected to the 110 volt circuit. At rated load the the motor takes 20 amperes, and is guaranteed to run 100% overload for short periods without sparking or overheating. The lathe used is of somewhat

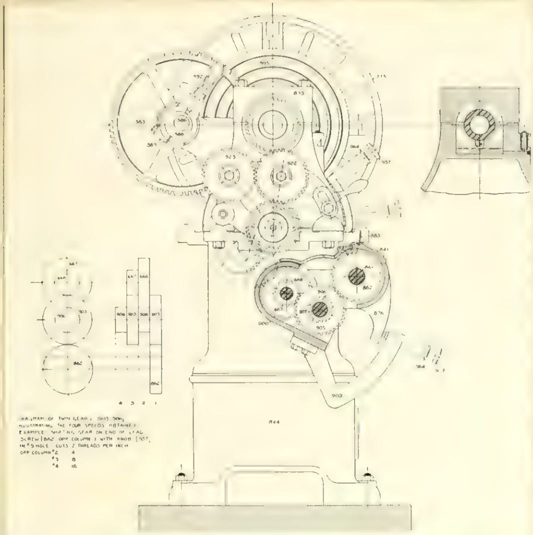


lighter construction than the one shown in the figure, otherwise it is of the same design. The lathe will swing a diameter of nine inches over the carriage. The motor, and the resistance and controller boxes, are mounted on an extended cabinet leg at the end of the lathe. The motor shaft is connected to the lathe spindle through a friction clutch and gear-



Headstock and Back Gears.

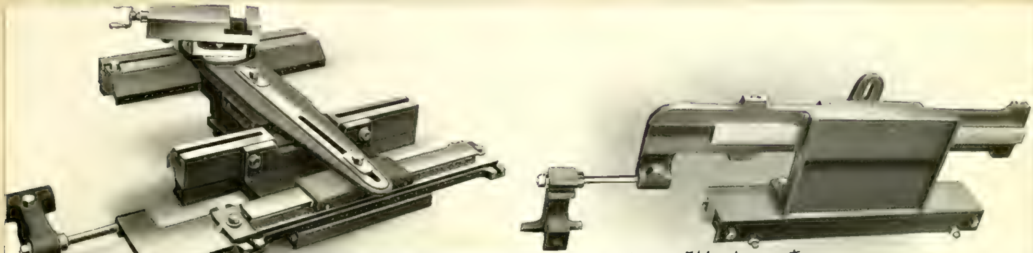
ing at the back of the headstock. The speed changes are secured by either varying the amount of resistance in the field coils of the motor, or by using a multiple voltage system. Ten different speeds for each gear change are secured by means of the controller. The motor used gives practically a constant horse power with a speed variation of two to one. The motor is connected to a short splined driving shaft, at the back of the lathe, on which is mounted a sliding sleeve with two gears of different diameters. These gears may be shifted so that the drive is through either one of them into the main driving gear on the sleeve. Two other changes are secured by means of either of two back gears. In this manner we can get six different speeds, and with the ten different controller notches we are able to get a total of 60 different speed changes. The motor is reversible, its direction of rotation being changed by means of the controller handle.


Feed Gear Changes

The back gearing is designed to give a uniform progression in speed from a slow to a fast speed. The two back gears are connected to the back gear shaft by spline and key, and are easily moved

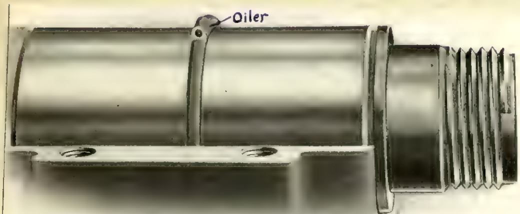
lengthwise to engage with their respective gears on the driving sleeve.

The lathe is provided with an attachment for cutting tapers, (see illustration). It is set for tapers by loosening the cross-feed screw and tightening the screw in the sliding block and in the dog. It may be instantly changed to turn straight by loosening the screw in the dog.



Two Views of the Compound Rest and Taper Attachment.

The bushings for the back gear shaft are placed at either end and are provided with oil reservoirs for self lubrication. In the center of the bearings for the spindle and driving sleeve, deep oil wells are cast, these are connected with gauge glasses at the front of the headstock, so the height of the oil in the reservoirs can always be seen.

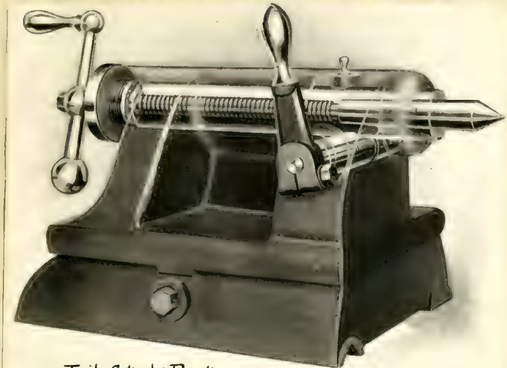


Lodge and Shipley Patent Main Bearing

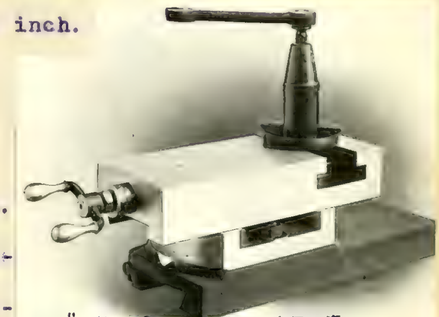
At the center of each bearing is fastened a brass ring with four projections, these projections act as buckets and pour the oil on the bearings.

The tail stock is very solidly built and has a long bearing on the bed. It is shaped so as to allow the compound rest to be set

at 90 degrees when using the tool on small diameters. Suitable screws are provided on the tail stock for setting over for taper work, and the base has a two inch index graduated to six-tenths of an inch.



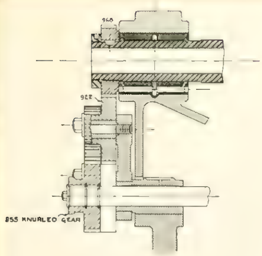
Tail Stock Rest



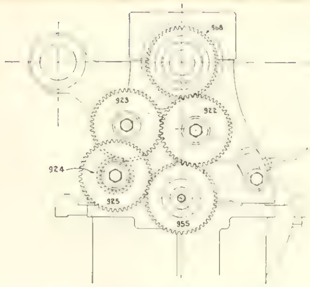
16" Lathe Compound Tool Rest

The range of feeds is very flexible. At the bottom of each column of the index plate is given the minimum and maximum feeds obtainable when the pointer is in that column. Intermediate speeds are secured by placing the knob in the holes indicated. The ratio of the feeds to the threads is two to one.

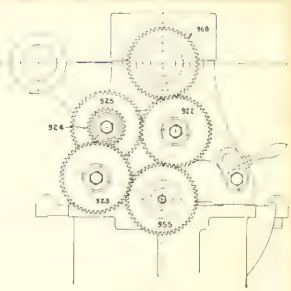
See the next page for the blue print of the table showing the various feeds or threads obtainable per inch.



POSITION OF KNURLED GEAR WHEN CUTTING EXTRA THREADS
THE DOTTED LINES SHOW THE POSITION WHEN CUTTING THE REGULAR THREADS OF INDEX



ARRANGEMENT OF SAME GEARS TO CUT EXTRA COARSE THREADS



TO CUT EXTRA FINE THREADS

Feed Index for Cutting Threads.

Thds.	Knob	Thds.	Knob	Thds.	Knob	Thds.	Knob	Thds.	Knob
36	2	18	2	9	2	4	2	2	2
38	3	19	3	9.5	3	4.5	3	2.25	3
40	4	20	4	10	4	4.75	4	2 3/8	4
44	5	22	5	11	5	5	5	2 1/2	5
46	6	23	6	11.5	6	5.5	6	2 3/4	6
48	7	24	7	12	7	6	7	3	7
52	8	26	8	13	8	6.5	8	3 1/4	8
56	9	28	9	14	9	7	9	3 1/2	9
60	10	30	10	15	10	7.5	10	3.75	10
64	11	32	11	16	11	8	11	4.0	11
		F E E D S							
128 to 72		64 to 36		32 to 18		16 to 8		8 to 4	

Put in Knurled Gear

Lodge and Shipley 16" patent head high speed lathe.

Calibration of the Controller

We went to considerable trouble in order to calibrate the handle on the controller so that any one of the ten notches in the controller box could be secured as desired.

TABLE of SPEEDS and GEARS.

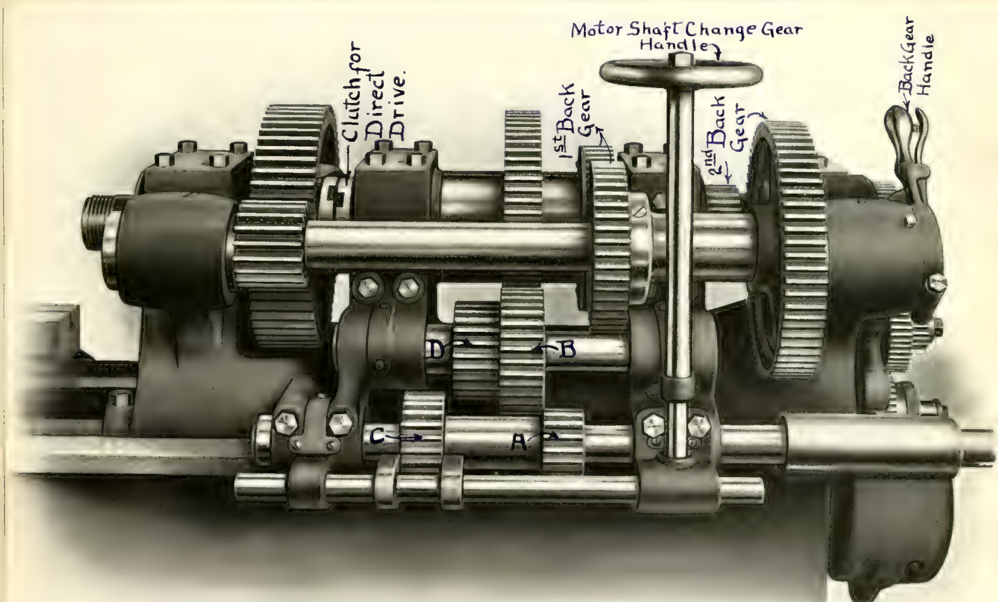
2 1/2 H.P. Northern variable speed motor: current, 20 amps. volts, 110: R.P.M., 500-1000: No. 16603.

Lodge and Shipley 16 in. patent head lathe.

The following table shows the actual lathe speeds at rated load of motor:-

GEARS	R.P.M.	DIRECT DRIVE	BACK GEARS	GEARS ON MOTOR SHAFT
1	0-26	out	2	AB
2	26-54	out	2	CD
3	40-84	out	1	AB
4	84-170	out	1	CD
5	122-260	in	out	AB
6	260-510	in	out	CD

For other speeds see efficiency tables.



Change Gears on 16" Lodge and Shipley High Speed Lathe.

Photograph showing lathe in readiness for efficiency tests with Prony brake in place.

EFFICIENCY TEST OF THE LATHE.

The object of the test was to determine the combined efficiency of the lathe and motor for various speeds and loads.

The results of the test are given in tables 1-6 and curve sheets 1-12 on the following pages.

The wiring of the lathe motor for the test was done as shown in the figure of electrical connections. A direct current watt-meter was placed in the circuit and calibrated as described elsewhere in the thesis.

A 12-inch pulley, taken from the Pelton water wheel, was mounted with set screw on a 2-inch shaft 18 inches long, and placed between centers on the lathe. A "dog" was placed on the head stock end in the usual manner. The pulley carried a strap form of Prony brake (see photograph). The brake arm rested on a strut supported on platform scales. The scales were calibrated by means of U.S. Standard weights and found to be correct. The notch on the brake arm was made 31.52 inches from the center of the shaft so that the forula for Brake Horse Power (B.H.P.) wouldbe simplified.

$$B.H.P. = \frac{2\pi r.N.P.}{33000} = \frac{2\pi 31.52xN.P.}{33000} = \frac{N.P}{2000}$$

where P = pressure on the scales minus the brake constant minus the weight of the strut, all in pounds. N = revolutions of pulley per minute.

The following method was pursued in conducting the brake tests. The watt-meter was connected up and placed in the position to give the correct reading when current was reversed in direction, by means

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A 12-inch pulley, taken from the Pelton water wheel, was mounted with set screw on a 2-inch shaft 15 inches long and placed between centers on the lathe. A "dog" was placed on the head stock and in the usual manner. The pulley carries a strap form of Prony brake (see photograph). The brake arm rested on a strut supported on platform scales. The scales were calibrated by means of U.S. Standard weights and found to be correct. The notch on the brake arm was made 31.52 inches from the center of the shaft so that the formula for Brake Horse Power (B.H.P.) would be simplified.

$$B.H.P. = \frac{2\pi N r P}{33000} = \frac{2\pi\, 2.62 \times N P}{33000} = \frac{N P}{2000}$$

where P = pressure on the scales minus the brake constant (including the weight of the strut, etc.) in pounds. N = revolutions of pulley per minute.

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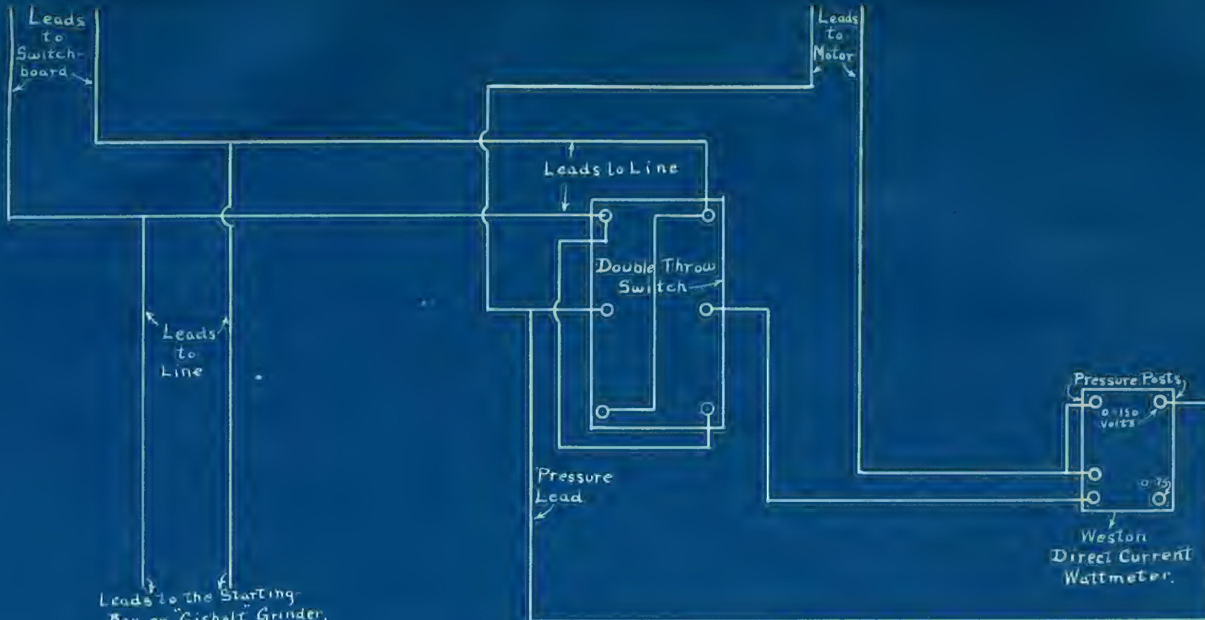

Diagram of Electrical Connections for "Thesis" Work

A.I.T. May 10, 1906

Fred Norwood Wilson.

Charles C. Hayes

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of the double throw switch. A piece of pork was used for a lubricant on the brake, and grease on the tail-stock point. As the brake heated up it was necessary to loosen the tail-stock so as to allow for the expansion of the pulley shaft.

A series of 280 runs were made, varying the brake load for each of 36 different spindle speeds. The following readings were taken for each run: (1) revolutions per minute of spindle-using speed counter; (2) watt-meter reading in kilowatts; (3) gross pounds on platform scales: (4) number of gears and controller used.

ELECTRICAL CONNECTIONS.

The manner of connecting up the electrical apparatus is shown in the accompanying figure. The watt-meter used was calibrated each day by reversing the direction of the current through the motor armature and field, (this did not change the direction of rotation of the motor) and through the watt-meter. The position of the watt-meter with respect to the earth's field was varied and a bar magnet, made of hardened soft steel, and magnetized, was placed about 1 1/2 feet from the watt-meter. The poles of the magnet were reversed with respect to the earth's poles, and the position of the magnet was parallel to the earth's field. The distance of the magnet from the watt-meter was varied until on reversing the current the reading of the watt-meter remained unchanged. The reversal of current was obtained by means of a double throw switch fastened by set screws to the side of the lathe.

of the double switch. A piece of pork was used for a lubricant on the brake and on the grease tail-stock point. As the brake heated up it was necessary to loosen the tail-stock so as to allow for the expansion of pulley shaft.

A series of 250 runs were made varying the brake load for each of 36 different spindle speeds. The following readings were taken for each run: (1) revolutions per minute of spindle-using speed counter; (2) watt-meter reading in kilowatts; (3) gross pounds on platform scales: (4) number of gears and controller used.

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RESULTS of EFFICIENCY TEST of 16" LATHE

TABLE I

Gears Controller	R.P.M. or N	Prony Brake Gross Pounds	Prony Brake Net or P Pounds	Motor Input K.W.	Input E.H.P.	Output B.H.P.	H.P. Loss	Efficiency BHP÷EHP
1 – 1	14	16.6	0.4	0.34	0.45	0.001	0.45	0.3
	14	85.1	68.9	0.80	1.07	0.48	0.58	45.0
	14	141.0	124.8	1.17	1.57	0.87	0.70	55.5
	13	160.5	144.3	1.32	1.77	0.93	0.81	53.0
	13	161.0	144.8	1.35	1.81	0.94	0.87	52.0
1 – 2	15	16.6	0.4	0.30	0.40	0.001	0.40	0.3
	15	70.0	53.8	0.67	0.90	0.40	0.49	45.0
	16	111.5	95.3	1.02	1.37	0.76	0.60	55.5
	13	151.0	134.8	1.37	1.84	0.87	0.96	47.5
1 – 3	18	16.6	0.4	0.34	0.45	0.003	0.45	.8
	18	50.0	33.8	0.62	0.83	0.30	0.52	36.5
	18	94.2	78.0	0.97	1.30	0.70	0.60	54.0
	18	124.0	107.8	1.32	1.77	0.97	0.80	55.0
	17.8	137.0	120.8	1.45	1.94	1.07	0.87	55.0
	17.7	175.0	158.8	1.82	2.44	1.41	1.03	58.0
1 – 4	22	16.7	0.5	0.32	0.43	0.005	0.43	1.2
	22	57.5	41.3	0.72	0.97	0.45	0.51	47.0
	21.7	103.5	87.3	1.27	1.71	0.94	0.76	55.5
	21.5	130.5	114.3	1.57	2.10	1.23	0.87	58.5
	21.0	153.0	136.8	1.81	2.43	1.43	1.00	59.0
	21.0	172.0	155.8	2.09	2.73	1.79	0.94	65.5
1 – 5	24.1	16.7	0.5	0.35	0.47	0.006	0.46	1.2
	24.0	36.0	19.8	0.55	0.73	0.237	0.50	32.0
	24	44.0	27.8	0.66	0.88	0.33	0.55	37.5
	24	76.7	60.5	1.07	1.43	0.72	0.71	50.5
	24	102.4	86.2	1.40	1.87	1.03	0.84	55.0
	24	134.5	118.3	1.82	2.44	1.42	1.02	58.0
	24	165.0	148.8	2.22	2.98	1.78	1.20	60.0
	24	173.0	156.8	2.33	3.12	1.88	1.24	60.0
1 – 6	30	16.6	0.4	0.37	0.49	0.006	0.49	1.2
	30	30.5	14.3	0.57	0.76	0.21	0.55	28.0
	30	49.2	33.0	0.82	1.10	0.49	0.60	45.0
	29	59.3	43.1	0.97	1.30	0.62	0.67	48.0
	28	89.0	72.8	1.39	1.86	1.02	0.84	55.0
	27	110.0	94.8	1.70	2.28	1.28	1.0	56.0
	26	138.0	121.8	2.12	2.85	1.58	1.27	55.0

LODGE and SHIPLEY 16" HIGH SPEED LATHE   2 1/2 E.H.P. NORTHERN MOTOR

Prony Brake Constant 16.2 lbs.   Radius of Brake Arm 31.52 inches $B.H.P. = \frac{P.N}{2000}$

ARMOUR INSTITUTE of TECHNOLOGY   MAY 25, 1906   THESIS

Charles G. Hayes
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RESULTS of EFFICIENCY TEST of 16" LATHE

TABLE II

LODGE and SHIPLEY 16" HIGH SPEED LATHE   2 1/2 E.H.P. NORTHERN MOTOR

Gears Controller	(N) R.P.M.	Prony Brake Gross Pounds	Prony Brake Net Pounds	Motor Input K.W.	Input E.H.P.	Output B.H.P.	H.P. Loss	Efficiency in %
2-1	30	16.6	0.4	0.45	0.60	0.006	0.59	1.0
	28	70.0	53.8	1.12	1.50	0.75	0.74	50.0
	27	106.0	89.8	1.60	2.14	1.21	0.92	56.5
	26	[illegible]	127.8	2.07	2.78	1.60	0.98	57.5
	25	161.5	145.3	2.40	3.22	1.81	1.40	56.5
	24	169.0	152.8	2.50	3.35	1.83	1.51	55.0
2-2	28	16.5	0.3	0.42	0.56	0.004	0.56	0.7
	30	54.5	38.3	0.94	1.26	0.57	0.68	45.5
	28	101.5	85.3	1.60	2.14	1.19	0.94	55.5
	28	135.0	118.8	2.10	2.82	1.66	1.15	52.0
	26	162.4	146.2	2.50	3.35	1.90	1.45	56.5
	26	172.0	155.8	2.65	3.55	2.02	1.52	57.0
2-3	36	16.7	0.5	0.46	0.61	0.01	0.60	1.4
	35	60.0	43.8	1.06	1.39	0.76	0.57	57.0
	34	85.0	68.8	1.61	2.16	1.17	0.99	54.0
	33	115.0	98.8	2.10	2.81	1.63	1.18	58.0
	33	142.5	126.3	2.60	3.48	2.02	1.46	58.0
	31	163.0	146.8	3.00	4.02	2.27	1.74	56.5
	32	174.0	157.8	3.22	4.32	2.52	1.79	58.5
2-4	42	16.6	0.4	0.52	0.70	0.008	0.69	1.1
	42	41.5	25.3	0.96	1.28	0.53	0.75	41.5
	43	71.0	54.8	1.57	2.11	1.18	0.93	56.0
	40	99.0	82.8	2.14	2.86	1.65	1.21	58.0
	39	113.5	97.3	2.45	3.28	1.90	1.38	58.0
	38	147.0	130.8	3.22	4.32	2.48	1.87	57.0
	37	162.5	146.3	3.62	4.85	2.71	2.19	56.0
2-5	53	16.6	0.4	0.54	0.72	0.01	0.71	1.3
	48	36.0	19.8	0.96	1.28	0.47	0.81	37.0
	30	55.5	39.3	1.42	1.90	0.59	1.31	31.0
	46	78.0	61.8	1.96	2.62	1.42	1.20	54.0
	46	91.5	75.3	2.60	3.48	1.73	1.75	50.0
	46	121.0	104.8	3.05	4.09	2.41	1.68	59.0
	44	136.0	119.8	3.47	4.65	2.64	2.01	56.5
2-6	60	16.4	0.2	0.60	0.80	0.006	0.80	0.7
	61	29.4	13.2	0.93	1.24	0.40	0.84	32.5
	54	50.9	34.2	1.49	2.00	0.92	1.07	46.0
	54	73.6	57.4	2.12	2.85	1.55	1.30	54.5
	51	103.3	87.1	3.00	4.02	2.22	1.80	55.0
	49	120.5	104.3	3.55	4.75	2.57	2.19	54.0

Prony Brake Constant - 16.2 lbs.   Radius of Brake Arm - 31.52 Inches   B.H.P. = $\frac{PN}{2000}$

Charles E. Hayes
Fred Norwood Wilson

ARMOUR INSTITUTE of TECHNOLOGY   MAY 25, 1906   THESIS

RESULTS of EFFICIENCY TEST of 16" LATHE

TABLE III

LODGE and SHIPLEY 16" HIGH SPEED LATHE 2½ E.H.P. NORTHERN MOTOR

Gears Controller	N RPM	Prony Brake Gross Pounds	Prony Brake Net Pounds	Motor Input K.W.	Input E.H.P.	Output B.H.P.	H.P. Loss	Efficiency %
3-1	42	16.6	0.4	0.33	0.44	0.008	0.43	1.9
	42	52.2	36.0	1.00	1.34	0.75	0.58	57.5
	41	82.0	65.8	1.63	2.18	1.35	0.83	62.0
	40	96.5	80.3	1.93	2.58	1.61	0.97	62.5
	39	120.0	103.8	2.47	3.32	2.02	1.30	61.0
	37	137.2	121.0	2.92	3.92	2.24	1.68	57.0
	37	150.2	134.0	3.30	4.42	2.47	1.95	56.0
3-2	50	16.6	0.4	0.32	0.43	0.01	0.42	2.3
	49	54.4	38.2	1.09	1.46	0.89	0.62	[illegible]
	43	72.3	56.1	1.52	2.03	1.20	0.83	59.5
	43	95.0	78.8	2.03	2.72	1.69	1.03	62.0
	41.5	114.5	98.3	2.54	3.41	2.03	1.37	60.0
	42	140.7	124.5	3.22	4.32	2.62	1.70	60.5
	42	153.0	136.8	3.52	4.71	2.87	1.84	61.0
3-3	56	16.5	0.3	0.35	0.47	0.008	0.46	1.8
	58	42.0	25.8	1.00	1.34	0.75	0.59	56.0
	52	67.4	51.2	1.67	2.25	1.33	0.92	59.0
	54	87.0	70.8	2.22	2.97	1.91	1.06	64.0
	50	110.0	93.8	2.84	3.81	2.34	1.47	61.5
	47	127.6	111.4	3.40	4.55	2.62	1.93	57.5
3-4	66	16.5	0.3	0.37	0.50	0.01	0.49	1.9
	63	39.0	22.8	1.05	1.47	0.72	0.75	49.0
	64	58.2	42.0	1.64	2.19	1.34	0.85	61.0
	62	78.7	62.5	2.28	3.06	1.94	1.12	63.5
	60	90.0	73.8	2.65	3.55	2.22	1.33	62.5
	57	105.0	88.8	3.15	4.22	2.52	1.70	60.0
	56	126.	109.8	3.97	5.31	3.07	2.24	58.0
3-5	80	16.5	0.3	0.43	0.57	0.01	0.56	2.08
	76	33.3	17.1	1.02	1.37	0.65	0.72	47.0
	79	58.0	41.8	1.89	2.53	1.65	0.87	65.0
	70	78.0	61.8	2.60	3.47	2.17	1.30	62.5
	66	91.6	75.4	3.27	4.37	2.49	1.88	57.0
	68	99.0	82.8	3.60	4.82	2.81	2.01	58.5
3-6	90	17.0	0.8	0.51	0.69	0.04	0.64	6.6
	88	28.3	12.1	0.92	1.23	0.53	0.70	43.0
	84	47.8	31.6	1.64	2.19	1.32	0.86	60.5
	83	56.0	39.8	1.92	2.58	1.65	0.93	64.0
	80	77.0	50.8	2.82	3.78	2.03	1.75	53.5
	76	87.0	70.8	3.20	4.29	2.79	1.56	63.5
	75	112.0	95.8	4.50	6.03	3.59	2.44	59.5

Radius of Brake Arm 31.52 inches $B.H.P. = \frac{PN}{2000}$

Prony Brake Constant 16.2 lbs.

Charles E. Hayes
Fred Norwood Wilson

ARMOUR INSTITUTE of TECHNOLOGY MAY 25, 1906 THESIS

RESULTS of EFFICIENCY TEST of 16" LATHE

TABLE IV

LODGE and SHIPLEY" HIGH SPEED LATHE 2½ E.H.P. NORTHERN MOTOR

Gears Controller	N. R.P.M.	Prony Brake Gross Pounds	Prony Brake Net Pounds	Motor Input K.W.	Input E.H.P.	Output B.H.P.	H.P. Loss	Efficiency %
4–1	90	16.6	0.4	0.47	0.63	0.01	0.61	2.8
	85	44.4	28.2	1.51	2.02	1.19	0.82	58.5
	82	59.5	43.3	2.12	2.84	1.78	1.08	62.5
	80	70.0	53.8	2.59	3.41	2.15	1.26	63.0
	78	78.4	62.2	2.90	3.88	2.42	1.46	62.5
	72	96.0	79.8	3.67	4.81	2.87	2.04	58.5
4–2	90	16.6	0.4	0.47	0.63	0.01	0.61	2.8
	90	33.6	17.4	1.12	1.50	0.78	0.72	52.0
	90	46.4	30.2	1.65	2.21	1.35	0.86	61.0
	90	54.2	38.0	1.98	2.65	1.71	0.94	64.5
	84	70.0	53.8	2.67	3.52	2.26	1.26	64.5
	85	83.0	66.8	3.25	4.35	2.83	1.51	65.0
	80	90.3	74.1	3.65	4.88	2.96	1.92	60.5
4–3	116	16.6	0.4	0.51	0.68	0.02	0.66	3.4
	114	28.0	11.8	1.05	1.40	0.67	0.73	48.0
	110	38.6	22.4	1.60	2.14	1.23	0.91	57.5
	102	47.7	31.5	2.07	2.77	1.61	1.16	58.0
	101	56.3	40.1	2.52	3.37	2.02	1.35	60.0
	96	66.2	50.0	3.02	4.05	2.40	1.65	59.0
	94	75.4	59.2	3.58	4.80	2.77	2.03	58.0
4–4	126	16.6	0.4	0.67	0.89	0.02	0.87	2.8
	127	25.5	9.3	1.21	1.62	0.59	1.03	36.5
	128	32.9	16.7	1.65	2.21	1.07	1.14	48.5
	121	38.6	22.4	2.02	2.70	1.36	1.34	50.0
	118	51.2	35.0	2.76	3.70	2.06	1.64	55.5
	118	56.7	40.5	3.20	4.28	2.39	1.89	55.0
	106	63.5	47.3	3.76	5.03	2.51	2.52	50.0
4–5	148	16.6	0.4	0.77	1.03	0.02	1.00	2.8
	154	24.2	8.0	1.23	1.64	0.61	1.03	37.0
	148	29.3	13.1	1.52	2.04	0.96	1.07	45.5
	137	39.4	23.2	2.15	2.87	1.59	1.28	55.5
	142	45.3	29.1	2.57	3.45	2.07	1.38	60.0
	127	60.6	44.4	3.73	5.00	2.82	2.18	56.5
4–6	180	16.6	0.4	0.85	1.14	0.03	1.10	3.1
	166	20.2	4.0	1.16	1.55	0.33	1.22	21.5
	172	27.1	10.9	1.67	2.23	0.94	1.29	42.0
	170	36.4	20.2	2.37	3.18	1.72	1.46	54.0
	154	43.5	27.3	2.97	3.98	2.11	1.88	53.0
	148	51.5	35.3	3.62	4.85	2.62	2.23	54.0

Prony Brake Constant - 16.2 lbs. Radius of Brake Arm - 31.52 inches $B.H.P. = \frac{PN}{2000}$

ARMOUR INSTITUTE of TECHNOLOGY - MAY 25, 1906 - THESIS -

Charles E. Hayden

Fred Norwood McLeod

RESULTS of EFFICIENCY TEST of 16" LATHE

TABLE V

LODGE and SHIPLEY HIGH SPEED LATHE 2½ E HP NORTHERN MOTOR

Gears & Controller	N RPM	Prony Brake Gross Pounds	Prony Brake Net Pounds	Motor Input KW	Input EHP	Output BHP	HP Loss	Efficiency %
5–1	133	16.8	0.6	0.44	0.59	0.04	0.55	6.7
	126	28.0	11.8	1.05	1.41	0.74	0.67	52.5
	122	37.6	21.4	1.60	2.14	1.30	0.79	60.5
	123	43.7	27.5	2.04	2.74	1.69	1.05	61.5
	126	51.9	35.7	2.56	3.42	2.25	1.17	65.5
	116	57.0	40.8	2.95	3.95	2.37	1.58	60.0
	110	66.0	49.8	3.62	4.85	2.74	2.11	57.5
5–2	150	16.9	0.7	0.45	0.60	0.05	0.55	8.7
	146	31.0	14.8	1.36	1.82	1.08	0.74	59.5
	154	34.0	17.8	1.58	2.12	1.37	0.75	64.5
	154	38.3	22.1	1.92	2.57	1.70	0.87	66.0
	146	47.2	31.0	2.59	3.47	2.26	1.21	65.0
	138	51.0	34.8	2.93	3.93	2.41	1.52	61.5
	130	56.9	40.7	3.42	4.57	2.64	1.93	58.0
5–3	179	17.1	0.9	0.45	0.60	0.07	0.52	13.0
	180	25.0	8.8	1.04	1.39	0.79	0.60	57.0
	169	32.5	16.3	1.64	2.19	1.34	0.85	61.0
	168	40.8	24.6	2.32	3.10	2.07	1.03	66.5
	166	47.0	30.8	2.92	3.91	2.57	1.34	67.0
	160	53.2	37.0	3.57	4.78	2.86	1.82	62.0
5–4	219	16.8	0.6	0.45	0.60	0.06	0.54	10.7
	196	25.1	8.9	1.17	1.57	0.87	0.70	55.5
	203	31.7	15.5	1.80	2.41	1.57	0.84	65.0
	192	41.5	25.3	2.67	3.57	2.43	1.14	68.0
	180	48.0	31.8	3.40	4.55	2.86	1.69	63.0
	172	52.4	36.2	3.95	5.29	3.11	2.18	59.0
5–5	230	16.6	0.4	0.49	0.65	0.04	0.61	7.0
	240	22.6	6.4	1.04	1.39	0.76	0.62	55.0
	222	27.0	10.8	1.50	2.01	1.20	0.79	59.5
	220	32.0	15.8	2.00	2.67	1.74	0.93	65.0
	222	37.7	21.5	2.57	3.45	2.38	1.07	69.0
	216	42.0	25.8	3.10	4.15	2.79	1.36	67.0
5–6	294	16.7	0.5	0.59	0.79	0.07	0.62	9.2
	289	23.0	6.8	1.32	1.77	0.96	0.81	54.5
	259	30.1	13.9	2.15	2.87	1.77	1.10	61.5
	264	34.8	18.6	2.72	3.65	2.46	1.19	67.5
	236	39.7	23.5	3.40	4.55	2.77	1.78	61.0
	236	42.9	26.7	3.95	5.29	3.16	2.13	60.0

Prony Brake Constant 16.2 lbs. Radius of Brake Arm 31.52 inches $B.H.P. = \frac{PN}{2000}$

ARMOUR INSTITUTE of TECHNOLOGY MAY 25, 1906 —THESIS—

Charles C. Hayes
Fred Norwood Wilson

RESULTS of EFFICIENCY TEST of 16" LATHE

TABLE VI

LODGE and SHIPLEY "HIGH SPEED" LATHE — 2 1/2 E.H.P. NORTHERN MOTOR

Gears Controller	N R.P.M.	Prony Brake gross Pounds	Prony Brake Net Pounds	Motor Input K.W.	Input E.H.P.	Output B.H.P.	H.P. Loss	Efficiency %
G-1	260	27.5	11.3	1.75	2.39	1.47	0.87	62.0
	254	31.7	15.5	2.27	3.04	1.97	1.07	64.0
	257	34.5	18.3	2.65	3.55	2.36	1.18	66.5
	240	36.4	20.2	3.05	4.08	2.42	1.66	58.5
	230	40.5	24.3	3.56	4.77	2.80	1.97	59.0
	216	46.0	29.8	4.50	6.03	3.22	2.80	52.0
G-2	290	16.6	0.3	0.5	0.67	0.43	0.23	65.0
	285	21.0	4.8	1.02	1.37	0.58	0.79	42.5
	288	24.5	8.3	1.45	1.94	1.19	0.75	61.5
	280	28.8	12.6	1.98	2.65	1.76	0.89	67.5
	270	33.0	16.8	2.50	3.35	2.27	1.08	68.0
	262	36.5	20.3	3.10	4.15	2.66	1.49	64.0
	240	44.5	28.3	4.15	5.56	3.40	2.16	39.0
G-3	340	16.9	0.7	0.57	0.74	0.12	0.62	16.0
	350	19.6	3.4	0.97	1.30	0.59	0.70	46.0
	348	22.5	6.3	1.40	1.87	1.18	0.89	59.0
	336	28.1	11.9	2.23	2.99	2.06	0.93	70.0
	320	30.2	14.0	2.55	3.42	2.24	1.18	65.5
	320	33.6	17.4	3.07	4.12	2.78	1.34	67.5
	300	35.5	19.3	3.54	4.75	2.89	1.86	63.0
G-4	420	16.7	0.5	0.65	0.87	0.10	0.76	12.0
	424	18.5	2.3	0.92	1.24	0.48	0.75	39.5
	418	21.6	5.4	1.52	2.03	1.13	0.90	55.5
	410	24.9	8.7	2.08	2.79	1.78	1.01	64.0
	392	27.7	11.5	2.65	3.55	2.15	1.40	60.5
	400	29.0	12.8	2.92	3.91	2.56	1.35	65.5
	350	34.4	18.2	3.95	5.30	3.18	1.10	60.0
G-5	460	16.7	0.5	0.67	0.89	0.11	0.78	12.8
	480	18.2	2.0	0.97	1.30	0.48	0.82	37.0
	453	20.9	4.7	1.52	2.03	1.06	0.97	52.0
	420	22.5	6.3	2.04	2.73	1.32	1.41	48.5
	416	26.0	9.8	2.60	3.48	2.04	1.44	58.5
	424	29.1	12.9	3.35	4.48	2.74	1.74	61.0
	400	32.3	16.1	4.06	5.43	3.22	2.21	59.5
G-6	574	16.8	0.6	0.77	1.03	0.17	0.85	16.7
	560	18.0	1.8	1.06	1.42	0.50	0.91	35.5
	512	20.7	4.5	1.68	2.25	1.15	1.10	51.0
	504	23.0	6.8	2.26	3.02	1.71	1.31	56.5
	484	25.4	9.2	2.93	3.93	2.22	1.71	56.5
	450	28.2	12.0	3.65	4.89	2.70	2.19	55.0

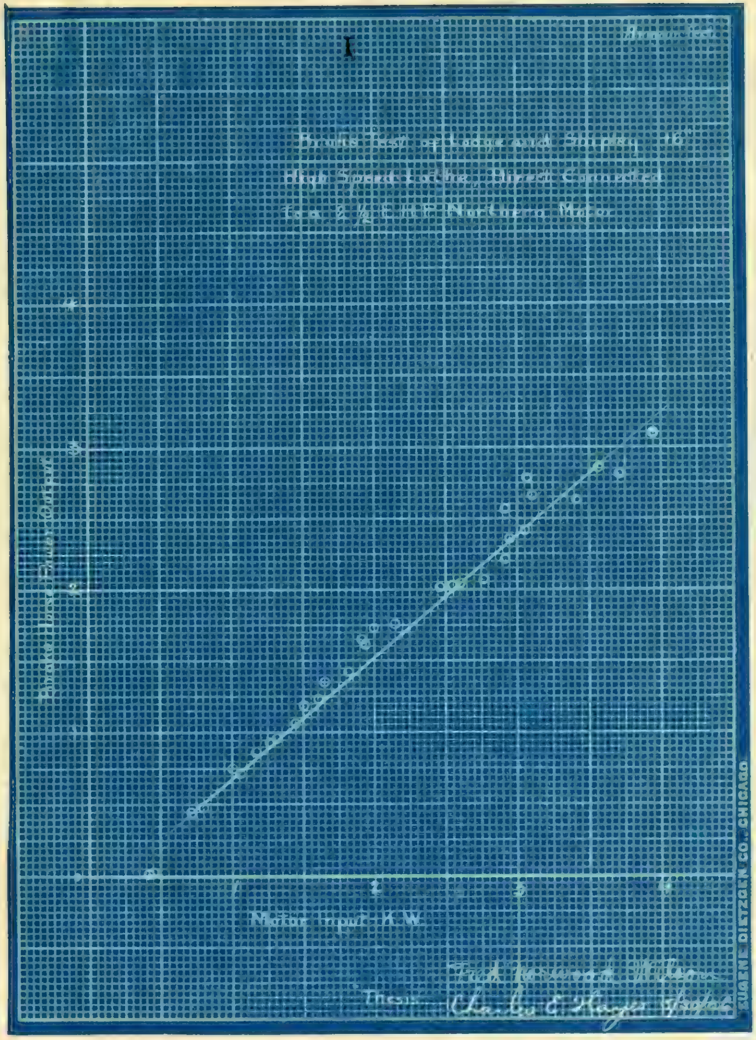
Prony Brake Constant — 16.2 lbs

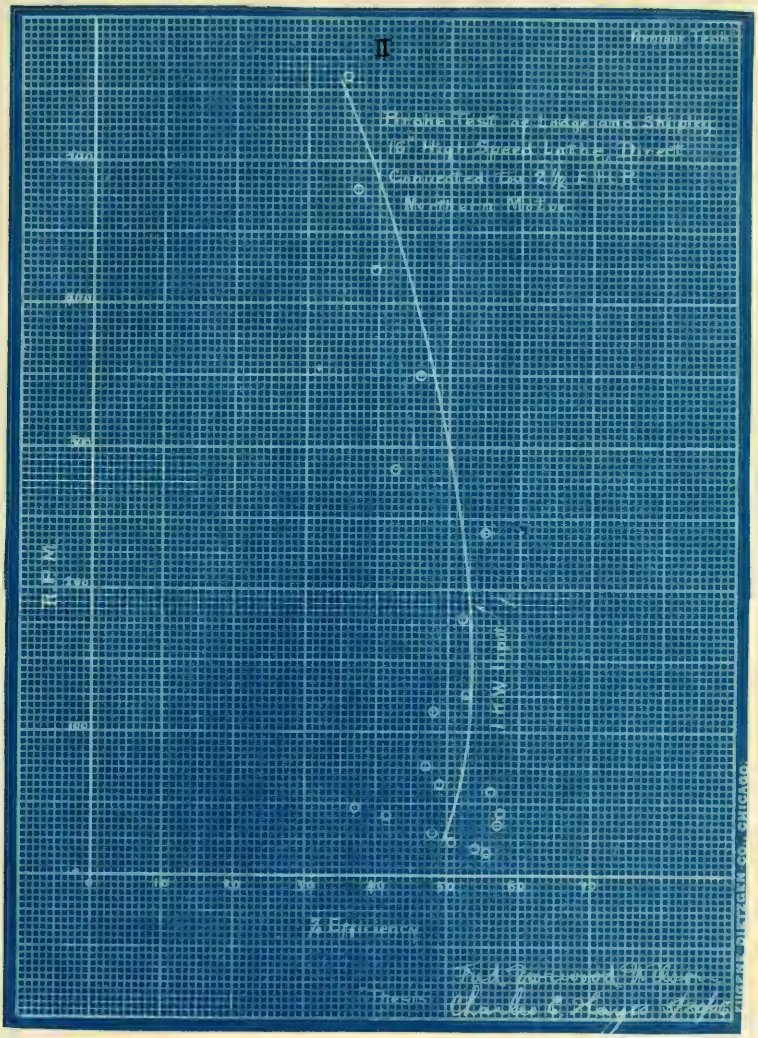
Radius of Brake Arm — 31.52 inches

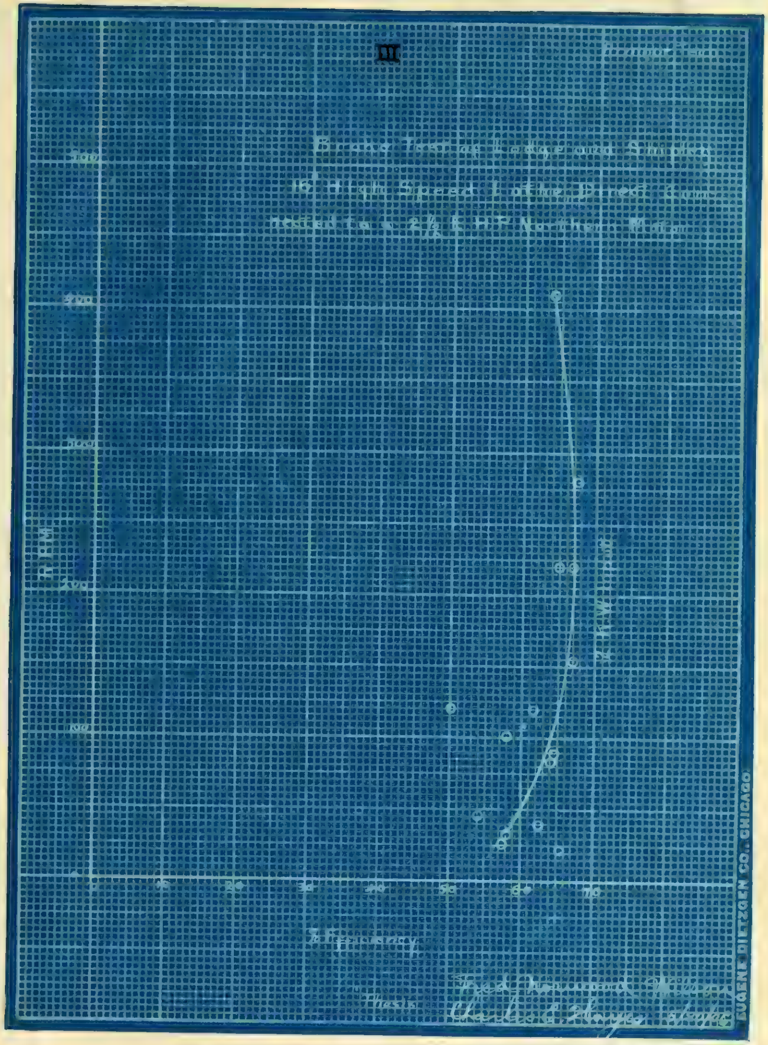
$$B.H.P. = \frac{P.N.}{2000}$$

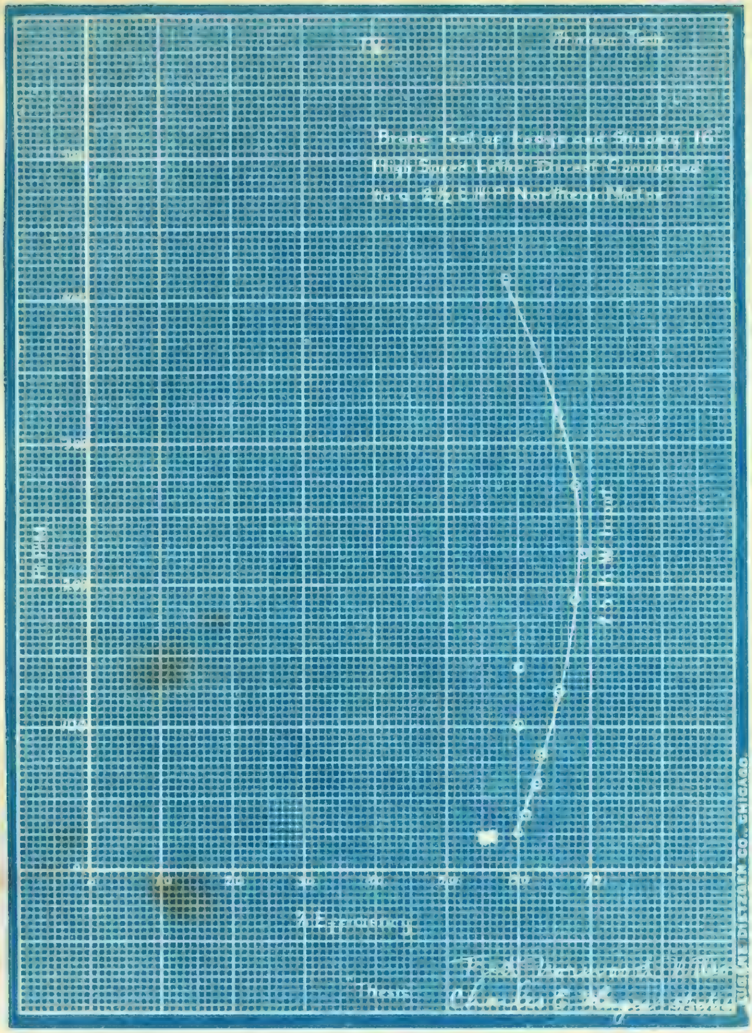
ARMOUR INSTITUTE of TECHNOLOGY MAY 25, 1906 THESIS

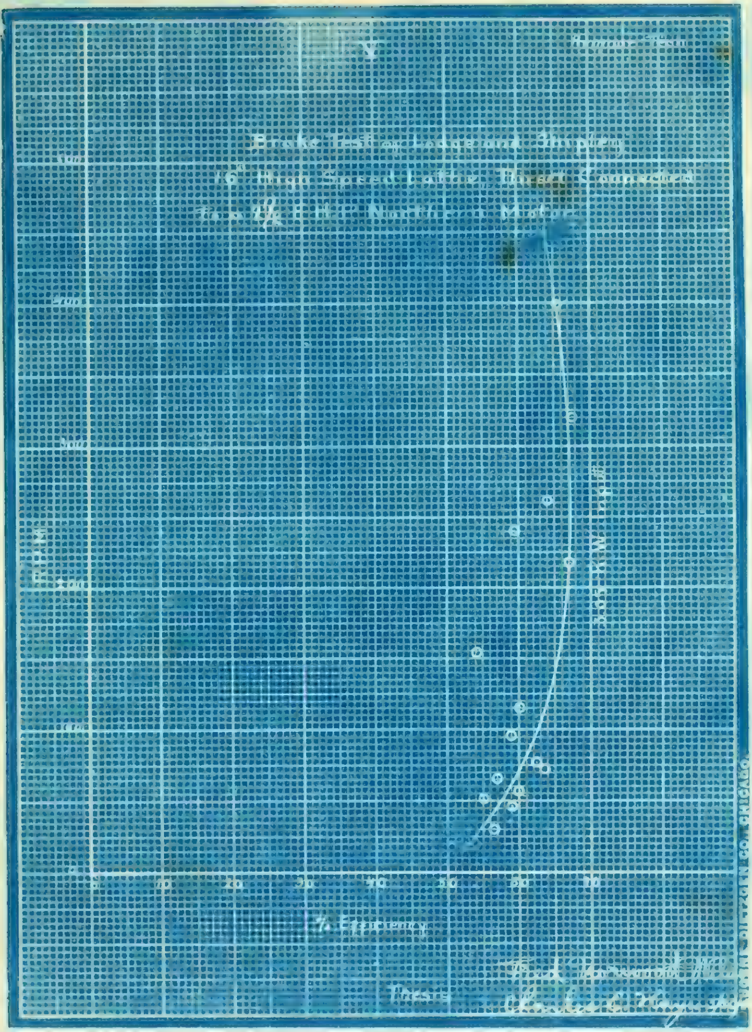
Charles G. Hayes
Fred [illegible]

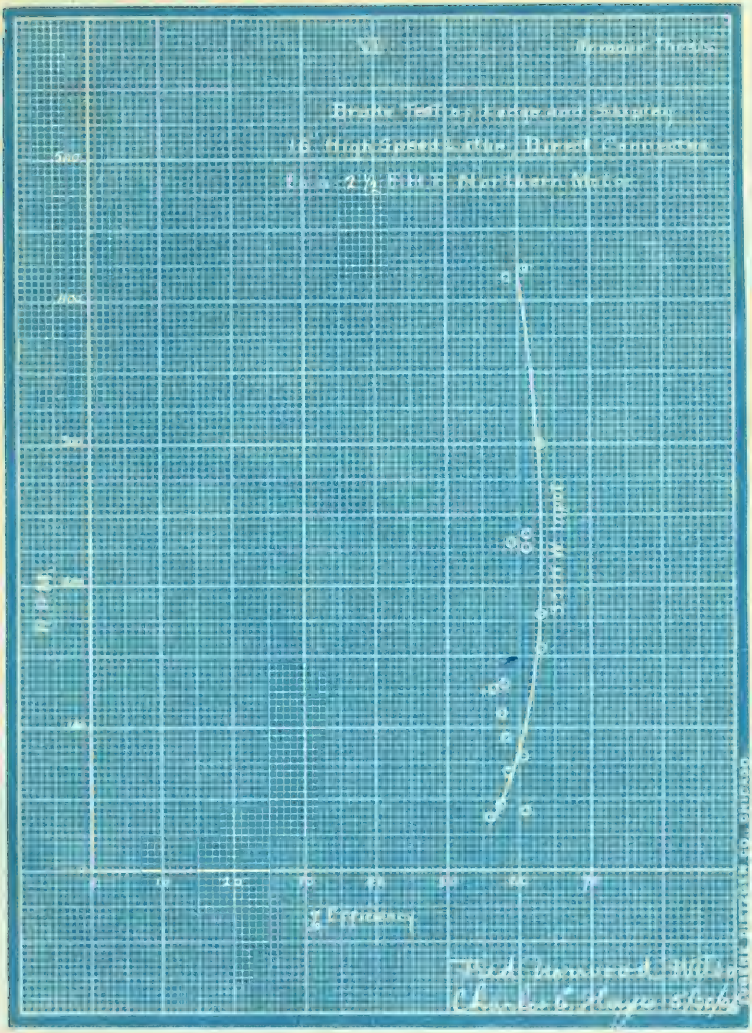

I
Brake Test of Lodge and Shipley 16"
High Speed Lathe, Direct Connected
to a 2 1/2 H.P. Northern Motor
Motor Input K.W.
1
2
3
4
EUGENE DIETZGEN CO. CHICAGO

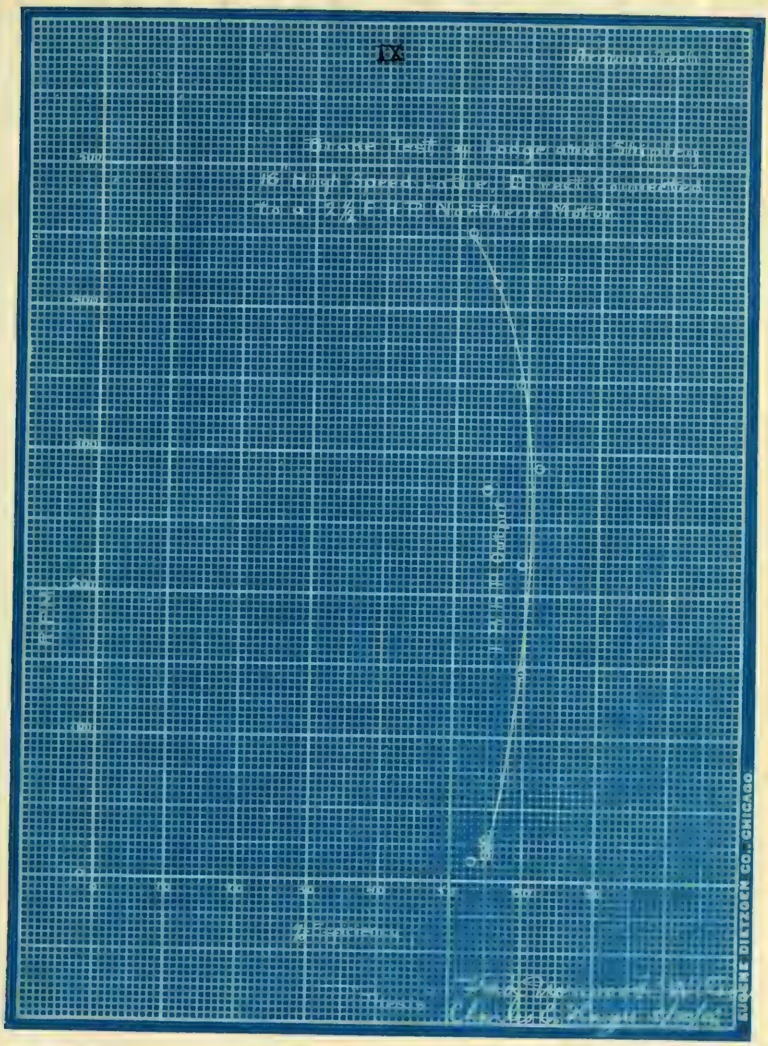

II
% Efficiency
EUGENE DIETZGEN CO. CHICAGO

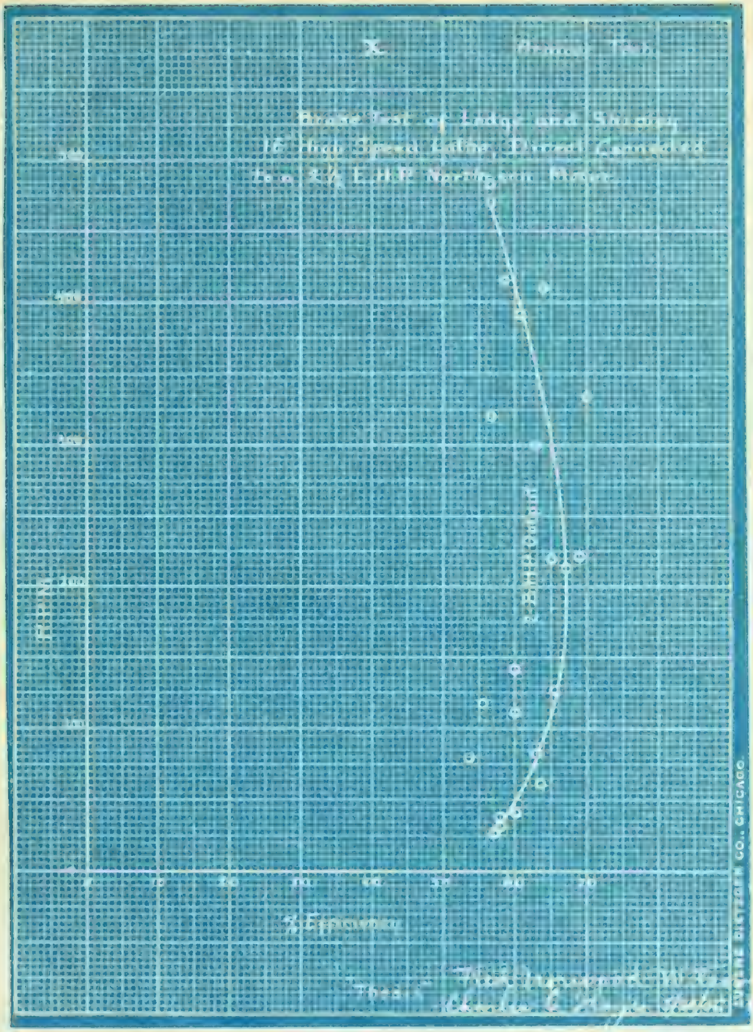

III
Brake Test of Lodge and Shipley
16" High Speed Lathe Direct Con-
nected to a 2½ H.P. Northern Motor
Efficiency
Thesis
EUGENE DIETZGEN CO. CHICAGO

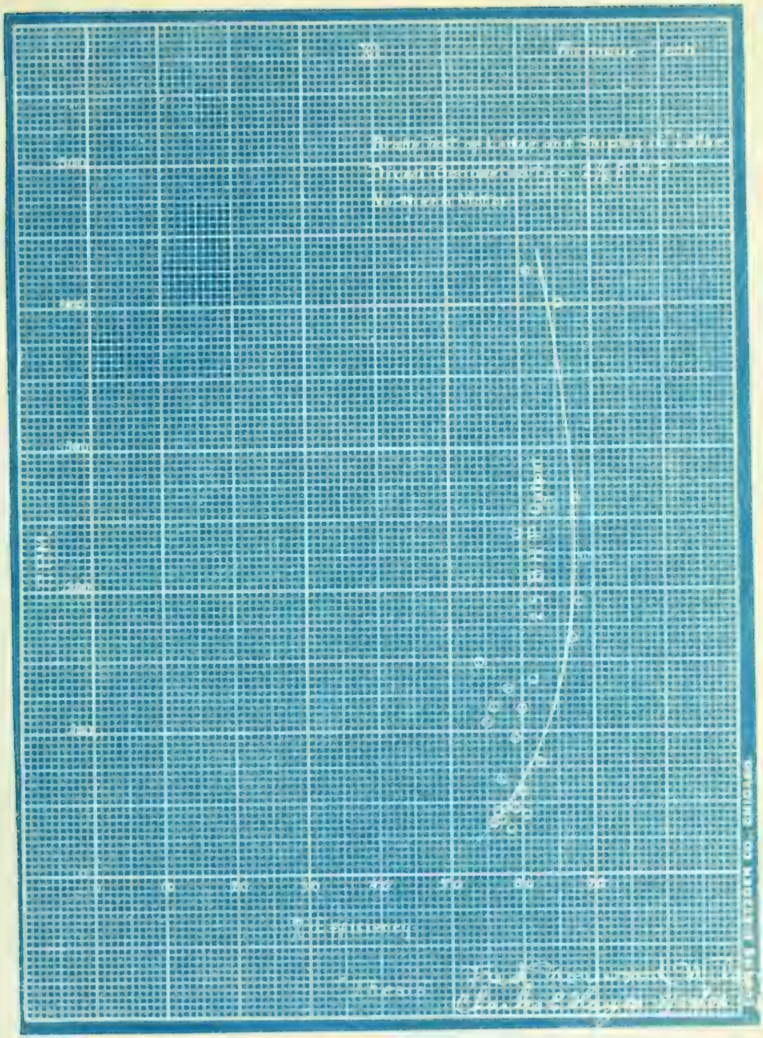

10
20
30
40
50
60
70
EUGENE DIETZGEN CO., CHICAGO

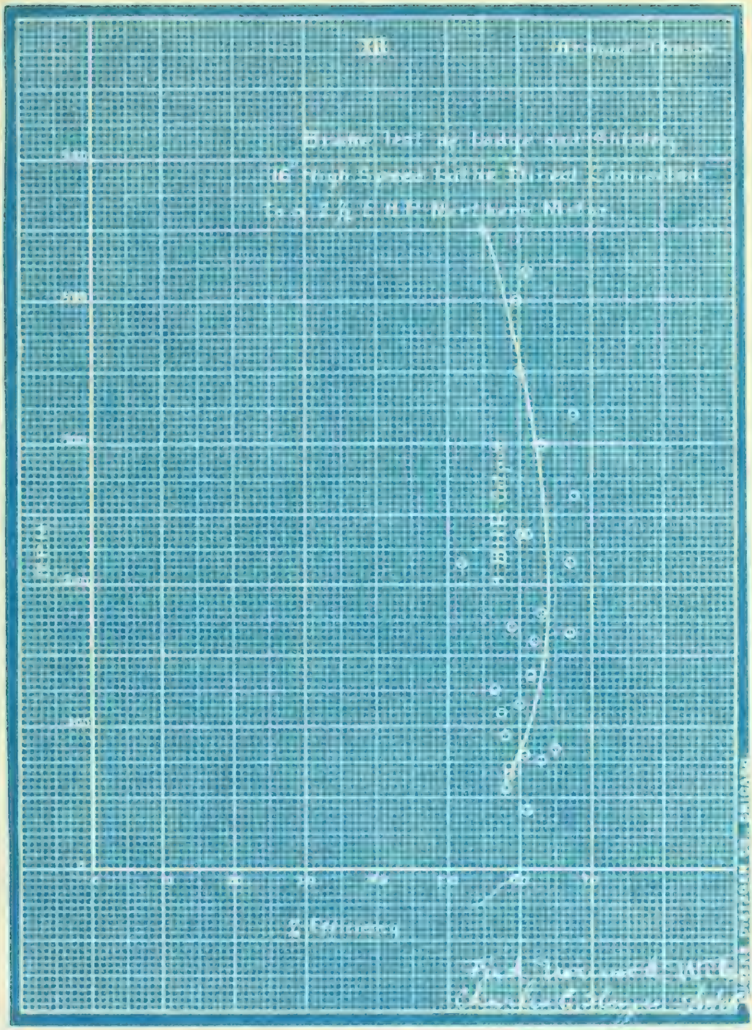

R.P.M.
10
20
30
40
50
60
70
% Efficiency


Armour Thesis
Brake Test of Lodge and Shipley
16" High Speed Lathe, Direct Connected
to a 2½ H.P. Northern Motor
500
400
300
200
100
0
10
20
30
40
50
60
70
% Efficiency


IX
Brake Test of Lodge and Shipley
16" High Speed Lathe, Direct Connected
to a 7½ H.P. Northern Motor
EUGENE DIETZGEN CO. CHICAGO


X
Brake Test of Lodge and Shipley
16" High Speed Lathe, Direct Connected
to a 2½ E.H.P. Northern Motor.
R.P.M.
B.H.P. Output
% Efficiency
0
10
20
30
40
50
60
70
100
200
300
400
500
Thesis
EUGENE DIETZGEN CO., CHICAGO.




XII
% Efficiency

DISCUSSION of RESULTS of the EFFICIENCY

TEST on a 16" LATHE.

The tables (I-IV) give the results of the brake tests on the lathe for 36 different gear and controller changes. For each one of these 36 variations in the spindle speed, the tables show the performance of the lathe for a load variation on the motor of from 12% of rated load (2.5 H.P.) to 100% overload. At the spindle speeds below 30 R.P.M. we were unable to screw the brake up tight enough to get an overload on the motor. The combined efficiency of motor and lathe throughout the range is also given. Twelve curves were plotted using the results obtained.

Curve I shows the brake horse power that can be secured with any motor input in K.W. throughout the range.

Curves (II-VII) inclusive show the efficiency variation in per cent for any number of R.P.M. Each one of these curves is for a certain constabt motor input in K.W. $EFF. = \frac{\text{Output in K.W.}}{\text{Motor input in K.W.}}$

Curve	Input-K.W.	R.P.M.	Max. Eff. %
II	1	175	53
III	2	225	67
IV	2.50	235	69
V	3.0	265	67.3
VI	3.5	225	63
VII	4.0	400	60

Curves (VIII-XII) inclusive show the efficiency variation in per cent for any number of R.P.M. Each one of the curves is for a certain constant brake-horse-power output.

[illegible]

[illegible]

The tables (I-IV) give the results of the brake tests on the lathe for 56 different gear and controller changes. For each one of these 56 variations in the spindle speed, the tables show the performance of the lathe for a load variation on the motor of from 12% of rated load (2.5 H.P.) to 100% overload. At the spindle speeds below 50 R.P.M. we were unable to screw the brake up tight enough to get an overload on the motor. The combined efficiency of motor and lathe throughout the range is also given. Twelve curves were plotted using the results obtained.

Curve I shows the brake horse power that can be secured with any motor input in K.W. throughout the range.

Curves (II-VII) inclusive show the efficiency variation in per cent for any number of R.P.M. Each one of these curves is for a certain constant motor input in K.W. $\left(\%, \frac{\text{output in K.W.}}{\text{motor input in K.W.}}\right)$

Curve	Input-K.W.	R.P.M.	Max. Eff. %
II	1	175	53
III	2	225	57
IV	2.5	245	[illegible]
V	3.0	[illegible]	[illegible]
VI	3.5	[illegible]	[illegible]
VII	4.0	[illegible]	[illegible]

Curves (VIII-XII) inclusive show the efficiency variation in per cent for any number of R.P.M. Each one of the curves is for a certain constant brake horse power output.

Curve	Output-B.H.P.	R.P.M.	Max.Eff.-%
VIII	0.5	150	48
IX	1.0	250	60.7
X	2.0	200	67.
XI	2.5	225	67.3
XII	3.0	200	64

The results show the highest efficiency for 69% at 34% overload on the motor. Taking a good value of 80% as the efficiency of the motor alone, that of the lathe at 34% overload would be 86.5%. The combined efficiency of both is 69%.

The controller on the lathe was calibrated so that by using the tables (I-VI) and the table of speeds and gears, it is possible, knowing the K.W. input, to set the lathe so as to secure within 2 R.P.M. of the actual number of revolutions, without using a speed counter or watch. In this manner the desired cutting speed for any piece of work can be obtained instantly without taking any trial cuts as is necessary using a Warner Cutmeter.

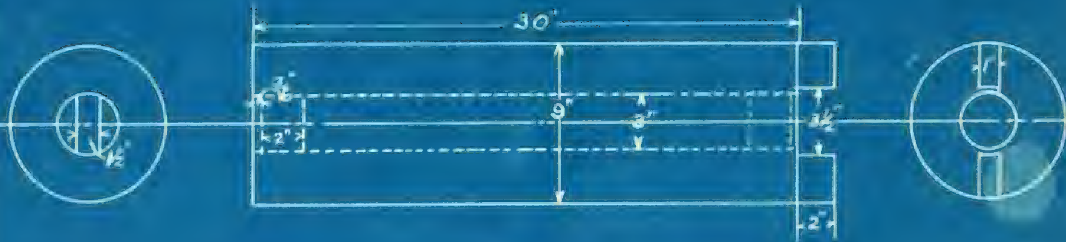
The actual amount of power consumed or the efficiency of the lathe and motor within certain limits is not so important as the saving of time in machining. However the efficiency results secured are of value to the makers of lathe-motors and lathes. The tables (I-VI) would be of value in making tests on lathes ,similar to the one used, to find the actual power required in cutting off metal. The proportioning of lathe parts to withstand the force acting on the tool is of great importance in the design of modern lathes.

PREPARATION of TEST PIECE for LATHE.

The cast iron test piece used in performing the tests on High Speed tool Steel is shown in the accompanying print and also in the photographs. The pattern was made in the pattern shop and four castings were cast in the foundry of ARMOUR INSTITUTEof TECHNOLOGY. Each one of these castings weighed 460 pounds. It was found necessar to place each test piece in the slotting machine to remove rough parts which necessitated considerable extra work. The ends of the test piece were centered by means of an electrically driven hand drill.

A special hook was made and placed in the ceiling above the lathe in order to support a block and tackle for handling the test pieces. Although the test piece used was very heavy the friction at the tail stock did not cause the bearing at that point to heat up appreciably.

A special chuck was machined in the slotter to hold the lugs on the headstock end of the test piece.



Standard form of Test Piece for Tests of
"High Speed Tool Steel" on Cast Iron.

A.I.T. May 20, 1906
Fred Norwood Wilson
Charles C. Hayes

DESCRIPTION of GRINDING MACHINE.

The tools were all uniformly ground on an electrically driven grinder made by the Gisholt Machine Co. The mechanism of the grinder is such that four different settings of a tool can be obtained, the angle of each setting being shown on a graduated scale. The carriage supporting the tool can be moved laterally by a hand wheel and brought up to the emery wheel by a lever. Running water is sprayed over the tool automatically while the grinder is in motion. The grinder is directly connected to a 5 H.P. motor. On the other end of the motor shaft is a small pulley carrying a 5/8 in. belt which runs over another pulley near the floor. The second pulley and shaft puts into action the device for supplying the spray of water. The same water is used over and over again. A starting box was placed on the wall near the grinder for permanent use.

DESCRIPTION of the DRILL PRESS

used for the HARDNESS TESTS on CAST IRON.

In order to have a fair test of the HighSpeed Steel tools used, the cast iron test pieces, on which the cutting is done, should be referred to a certain standard of hardness. The hardness of iron affects the cutting speed more than any other quality, therefore, a comparative hardness test is quite necessary. In order to carry on this test a drill press, made by S.W.Putnam Sons, Fitchburg, Mass., was fitted up as follows: the hand-wheel rim was graduated by means of a milling machine so that the passage of one division of the scale by a fixed pointer indicated a travel of one-hundredth of an inch of depth of drill. The number of divisions necessary(420)was found by noting the travel of a point on the drill for one revolution of the hand-wheel. This distance was 4.20 inches. A device was attached to the lever of the drill press on which a weight of 50 pounds could be hung.

By means of this apparatus the comparative hardness of two or more pieces of metal may be found as follows. Adopt one piece of metal as the standard. In our tests we took a grey iron casting 2"x2"x12" made in the foundry of the ARMOUR INSTITUTE of TECHNOLOGY.

With the drill rotating at a constant speed the rate of feed of the drill in inches per minute is secured taking readings every 0.1 inch drilled. A Morse standard 1/2 inch drill is used in the test, ground to an angle of 60 degrees. As the sharpness of the drill is liable to vary, a short preliminary run is made on the standard test

DESCRIPTION OF THE APPARATUS

used for the HARDNESS TESTS OF CAST IRON.

In order to have a fair test of the Hardened steel tools used, the cast iron test pieces, on which the cutting is done, should be referred to a certain standard of hardness. The hardness of iron affects the cutting speed more than any other quality, therefore, a comparative hardness test is quite necessary. In order to carry on this test a drill press, made by J.W.Putnam Sons, Fitchburg, Mass., was fitted up as follows: the hand-wheel rim was graduated by means of a milling machine so that the passage of one division of the scale by a fixed pointer indicated a travel of one-hundredth of an inch of depth of drill. The number of divisions necessary (420) was found by noting the travel of a point on the drill for one revolution of the hand-wheel. This distance was 4.20 inches. A device was attached to the lever of the drill press on which a weight of 50 pounds could be hung.

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Photograph of drill press showing arrangement for hardness test on cast iron specimen.

Figure IV

piece previous to each regular run. In this manner a comparison can always be obtained with a standard. The comparative hardness of the test piece is one hundred times the depth in inches drilled per minute in the standard specimen, divided by the depth in inches per minute drilled in the test piece. This is assuming one hundred as the hardness of the standard cast iron. The forgoing method was secured from a report written by Prof. J. T. Nicolson of the Manchester Municipal School of Technology, Manchester, England.

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Test of the HIGH SPEED STEEL TOOLS.

The test of the high speed steel tools on the cast iron specimens were conducted in the following manner: two tools from each of six different grades of steel were forged, hardened, and ground as described elsewhere in the thesis. The front clearance on the tools (6°-10°) was secured by hand on the emery wheel.

All tools were placed in the tool rest perpendicular to the center line of the work. The nose of the tool was adjusted from 1/8 to 1/4"* above the center line of the work. This was secured by means of a steel rule supported at the correct height above the ways on two blocks of wood placed on end.

Before starting the test all moving parts of the lathe were oiled. A wooden box 1'x1'x2' was made and placed under the lathe bed to catch the chips. All the cuttings removed during a run were swept up, placed in this box, and weighed on platform scales. Pieces of sheet metal were cut and put about the tool when in use so as to keep tool rest as clean as possible. In order to prevent slippage the set screw on the tool rest, and bolts on the carriage and on the tail stock were screwed up tightly.

The feed in inches per revolution was secured by means of the table on gears for thread cutting. The number of revolutions per inch of longitudinal travel of tool is two times the number of threads set. These feeds are accurate as we found by calibration.

The desired depth of cut was obtained by means of the graduated scale on the upper tool rest cross feed screw. The actual depth of cut was secured by finding the circumference of the test

Test of the Cast Iron Specimens.

The test of the high speed steel tools on the cast iron specimens were conducted in the following manner: two tools from each of six different grades of steel were forged, hardened, and ground as described elsewhere in the thesis. The front clearance on the tools (6-10) was secured by hand on the emery wheel.

All tools were placed in the tool rest perpendicular to the center line of the work. The nose of the tool was adjusted from 1/8 to 1/4" above the center line of the work. This was secured by means of a steel rule supported at the correct height above the ways on two blocks of wood placed on end.

Before starting the test all moving parts of the lathe were oiled. A wooden box 1'x1'x2' was made and placed under the lathe bed to catch the chips. All the cuttings removed during a run were swept up, placed in this box, and weighed on platform scales. Pieces of sheet metal were cut and put about the tool when in use so as to keep tool rest as clean as possible. In order to prevent slippage the set screw on the tool rest, and bolts on the carriage and on the tail stock were screwed up tightly.

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The desired depth of cut was obtained by means of the graduated scale on the upper tool rest cross feed screw. The actual depth of cut was secured by finding the circumference of the test

Photograph showing lathe in readiness for a test of

HIGH SPEED STEEL on Cast Iron.

Relative Diameters, Speeds and Revolutions

Diameter	Feet per minute										
	15	20	25	30	35	40	45	50	60	70	80
	Revolutions per minute										
1/4	229	306	382	458	535	611	688	764	917	1070	1222
5/16	183	245	306	367	428	489	550	611	733	856	978
3/8	153	204	255	306	357	408	458	509	611	713	815
7/16	131	175	218	262	306	349	393	437	524	611	699
1/2	115	153	191	229	268	306	344	382	459	535	611
3/8	91.8	123	153	184	214	245	276	306	367	428	489
3/4	76.5	102	127	153	178	203	299	254	306	357	408
7/8	65.5	87.3	109	131	153	175	196	219	262	306	349
1	57.3	76.4	95.5	115	134	153	172	191	229	267	306
1 1/8	51	68	85	102	119	136	153	170	204	238	272
1 1/4	45.8	61.2	76.3	91.8	107	123	137	153	183	214	245
1 3/8	41.7	55.6	69.5	83.3	97.2	111	125	139	167	195	222
1 1/2	38.2	50.8	63.7	76.3	89.2	102	115	127	153	178	204
1 5/8	35	47	58	70.5	82.2	93.9	106	117	141	165	188
1 3/4	32.7	43.6	54.5	65.5	76.4	87.3	98.2	109	131	153	175
1 7/8	30.6	40.7	50.9	61.1	71.3	81.5	91.9	102	122	143	163
2	28.7	38.2	47.8	57.3	66.9	76.4	86	95.5	115	134	153
2 1/4	25.4	34	42.4	51	59.4	68	76.2	85	102	119	136
2 1/2	22.9	30.6	38.2	45.8	53.5	61.2	68.8	76.3	91.7	107	122
2 3/4	20.8	27.8	34.7	41.7	48.6	55.6	62.5	69.5	83.4	97.2	111
3	19.1	25.5	31.8	38.2	44.6	51	57.3	63.7	76.4	89.1	102
3 1/2	16.4	21.8	27.3	32.7	38.2	43.6	49.1	54.5	65.5	76.4	87.4
4	14.3	19.1	23.9	28.7	33.4	38.2	43	47.8	57.3	66.9	76.4
4 1/2	12.7	16.9	21.2	25.4	29.6	34	38.2	42.4	51	59.4	67.9
5	11.5	15.3	19.1	22.9	26.7	30.6	34.4	38.2	45.9	53.5	61.1
5 1/2	10.4	13.9	17.4	20.8	24.3	27.8	31.3	34.7	41.7	48.6	55.6
6	9.6	12.7	15.9	19.1	22.3	25.5	28.7	31.8	38.2	44.6	51
7	8.1	10.9	13.6	16.4	19.1	21.8	24.6	27.3	32.7	38.2	43.7
8	7.2	9.6	11.9	14.3	16.7	19.1	21.1	23.9	28.7	33.4	38.2
9	6.4	8.5	10.6	12.7	14.9	17	19.1	21.2	25.5	29.7	34
10	5.7	7.6	9.6	11.5	13.4	15.3	17.2	19.1	22.9	26.7	30.6
11	5.2	6.9	8.7	10.4	12.2	13.9	15.6	17.4	20.8	24.3	27.8
12	4.8	6.4	8	9.6	11.1	12.7	14.3	15.9	19.1	22.3	25.5
13	4.4	5.9	7.3	8.8	10.3	11.8	13.2	14.7	17.6	20.6	23.5
14	4.1	5.5	6.8	8.1	9.6	10.9	12.3	13.6	16.4	19.1	21.8
15	3.8	5.1	6.4	7.6	8.9	10.2	11.5	12.7	15.3	17.8	20.4
16	3.6	4.8	6	7.2	8.4	9.6	10.7	11.9	14.3	16.7	19.1
18	3.2	4.2	5.3	6.3	7.4	8.5	9.5	10.6	12.7	14.8	17.
20	2.8	3.8	4.8	5.7	6.7	7.6	8.6	9.6	11.4	13.3	15.3
22	2.6	3.4	4.3	5.2	6.1	6.9	7.8	8.7	10.4	12.1	13.9
24	2.4	3.2	4	4.8	5.5	6.3	7.1	7.9	9.5	11.1	12.7

piece at three points before and after each run using a steel tape. Dividing the mean circumference by π and taking 1/2 the difference between the diameters before and after the cut, gives the actual depth of cut. The revolutions per minute of the spindle to give the desired approximate cutting speed, ~~was~~ were secured as follows:

$$R.P.M. = \frac{\text{desired cutting speed in ft./min.} \times 3.82}{\text{diameter of work in inches}}$$

Referring to the tables of the efficiency test of the lathe and knowing by trial the power in K. W. required to take a certain cut, we were able to secure a certain gear change and controller notch that would give the desired R. P. M. of the spindle in order to secure a cutting speed of from 15 to 80 ft./min. on work of from 1/4 inch to 24 inches in diameter. This table is very convenient but the formula was used for speeds greater than 80 ft./min.

The following data was taken during the test:

Brand and number of tool used.

Number of test.

Feed set in inches per revolution.

Cut set.

Mean circumference of work before run.

" " " " after "

Diameter of work before run.

" " " after "

Actual cut in inches.

R.P.M. by hand speed counter.

Duration of run in minutes.

Weight of iron removed in pounds.

Number of gears and controller used.

K.W. from watt-meter--no load.

" " " " --with load.

Rake on tool-front to back.

" " " -side to side.

Clearance on tool-front.

" " " -side.

Angle between cutting edge, and side of tool.

Why run was stopped.

Condition of tool after run.

Number of temper on tool.

" " test piece.

The point of the tool was ground after its condition went below "good".

An "excellent" tool was one on which no perceptible change was noted on the cutting edge.

A "good" tool was one which showed no bad effects and could keep up the cut across the test piece (30") without the work showing any taper.

A "fair" tool was one which could keep up the cut across the test piece but left the work tapered.

A "failed" tool would not sustain the cut one-half the way across the test piece.

Make of

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Novo
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Blue C
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Bohler R
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Vulcan
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Tests of High Speed Tool Steel on Cast Iron — 16" Elec. Driven High Speed Lathe. A.T.I. May 26, 1906 — Charles [illegible] / Fred Norwood Wilson — Thesis

Table VII

Make of Tool	Tool Number	Test Number	Cutting Speed	Initial Diam Test Piece	Final Diam Test Piece	Actual Cut	Actual Feed	R.P.M.	Wt. Cast Iron Pounds			Time		K.W.	K.W.	Area of Test Piece Machined in Square Feet		Condition of Tool	Cause of Withdrawal	Area of Section of Cut	Top Rake	Side Rake	Front Clear.	Side Clear.	Temper on Tool	Initial Circumference	Final Circumference	Cubic Inches Cast Iron	Test Piece	Gears	Controller	
			Ft./min.	Inches	Inches	Inches	In./Rev.		Total	/min.	/hr.	min.	sec.	No Load	Under Load	Per min.	Total			Sq. In.	Degrees				N°	Inches	Inches	/min.	N°	N°	N°	N°
McInnes	1	1	59.4	8 27/64	8.30	.06	.0625	28	5.8	.724	43.4	8	0	.47	1.25	.321	2.565	Ex.	end	.00375	0	30	6-10	6	16	26.45	26.00	2.7	1	2	1	15°
do	1	2	95.8	8 9/64	8.04	.048	do	45	4.6	.906	54.3	5	5	.55	1.6	.500	2.535	do	do	.00300	"	30	"	"	do	25.55	25.25	3.4	1	2	4	do
do	1	3	126.8	8 5/64	8.00	.042	do	60	4.1	1.064	63.8	3	51	.63	1.77	.660	2.540	do	do	.0026	"	"	"	"	do	25.38	25.10	4.0	1	2	6	do
do	1	4	134.0	8 1/64	7.91	.05	do	64	5.1	1.39	83.4	3	20	.37	2.0	.700	2.332	good	do	.0031	"	"	"	"	do	25.20	24.77	5.3	1	3	4	do
do	1	5	167.0	7 57/64	7.81	.04	do	81	3.7	1.53	91.8	2	25	.45	2.6	.771	1.860	failed	failed	.0025	"	"	"	"	do	24.80	24.50	5.9	1	3	6	do
Novo	1	6	116.0	7 11/16	7.57	.06	do	58	6.1	1.61	96.6	3	47	.63	2.3	.606	1.863	good	end	.0037	"	"	"	"	15	24.10	24.04	6.2	1	2	6	do
do	1	7	125.0	7.55	7.465	.041	do	63	3.7	1.12	67.2	3	17	.37	1.52	.640	2.100	do	do	.0026	"	"	"	"	do	23.75	23.38	4.3	1	3	4	do
do	1	8	161.0	7.47	7.38	.04	do	82	3.1	1.24	74.5	2	33	.43	2.25	.833	2.125	failed	failed	.0025	"	"	"	"	do	23.45	23.20	4.7	1	3	6	do
Blue Chip	1	9	106.5	7.38	7.24	.07	do	55	4.5	1.24	74.5	3	37	.65	1.83	.554	2.00	good	end	.0044	"	"	"	"	13	23.21	22.75	4.7	1	2	6	do
do	1	10	115.8	7.24	7.15	.045	do	61	3.8	1.19	71.5	3	12	.35	1.5	.604	1.933	do	do	.0028	"	"	"	"	do	22.78	22.44	4.6	1	3	4	do
do	1	11	155.0	7.15	7.05	.050	do	83	3.3	1.39	83.6	2	28	.47	2.08	.809	2.0	do	do	.0031	"	"	"	"	do	22.45	22.15	5.3	1	3	6	do
do	1	12	159.0	7.05	6.968	.041	do	86	2.4	1.61	57.6	2	30	.42	2.1	.836	2.090	failed	do	.0025	"	"	"	"	do	22.18	21.77	6.2	1	4	2	do
Böhler Rapid	1	13	110.0	7.78	7.63	.075	do	54	5.8	1.39	83.6	4	10	.64	1.77	.573	2.390	good	do	.0047	"	"	"	"	20	24.46	23.9	5.3	1	2	6	do
do	1	14	126.0	7.63	7.53	.05	do	63	4.7	1.32	78.2	3	38	.32	1.67	.655	2.380	do	do	.0031	"	"	"	"	do	24.00	23.6	5.1	1	3	4	do
do	1	15	170.0	7.53	7.43	.05	do	86	4.5	1.59	95.2	2	50	.47	2.33	.883	2.500	poor	do	.0031	"	"	"	"	do	23.65	23.27	6.1	1	3	6	do
do	1	16	157.3	7.43	7.324	.053	do	81	4.0	1.42	85.3	2	49	.40	2.25	.819	2.310	failed	failed	.0033	"	"	"	"	do	23.31	22.95	5.5	1	4	1	do
Vulcan	1	17	106.6	7.324	7.19	.067	do	54	5.1	1.28	77.1	3	58	.60	1.75	.540	2.140	good	end	.0042	"	"	"	"	18	23.63	22.5	4.9	1	2	6	do
do	1	18	120.6	7.19	7.074	.058	do	64	4.5	1.25	75.0	3	36	.40	1.6	.629	2.265	do	do	.0036	"	"	"	"	do	22.62	22.2	4.8	1	3	4	do
do	1	19	141.0	6.98	6.87	.055	do	77	3.9	1.31	78.8	2	58	.45	2.1	.731	2.170	do	do	.0034	"	"	"	"	do	21.93	21.5	5.0	1	3	6	do
do	1	20	153.0	6.	—	—	do	85	—	—	—	—	—	—	—	.795	—	failed	failed	—	"	"	"	"	do	21.56	—	—	1	4	2	do
Albion	5	21	99.0	6.77	6.65	.06	do	56	4.7	1.22	73.2	3	51	.60	1.75	.516	1.970	good	end	.0037	"	"	"	"	0	21.28	20.8	4.7	1	2	6	do
do	5	22	111.5	6.65	6.52	.065	do	64	4.3	1.23	74.0	3	29	.35	1.675	.566	2.160	do	do	.004	"	"	"	"	0	20.90	20.5	4.7	1	3	4	do
do	5	23	145.5	6.52	—	—	do	85	4.0	—	—	—	—	—	—	.754	—	failed	failed	—	"	"	"	"	0	20.43	—	—	1	3	6	do
McInnes	1	24	86.7	6.38	6.165	.107	do	52	7.6	1.63	97.8	4	20	.325	2.35	.453	1.960	good	end	.0067	"	"	"	"	16	20.04	19.37	6.3	1	3	3	15°
do	1	25	117.0	7.09	6.87	.105	do	63	8.0	2.17	136.5	3	31	.35	2.85	.610	2.145	"	"	.0065	"	"	"	"	"	22.28	21.59	8.7	1	3	4	do
do	1	26	126.0	6.87	6.64	.115	do	70	8.1	2.57	154.2	3	9		3.80	.655	2.062	limit	"	.0072	"	"	"	"	"	21.59	20.87	9.9	1	3	5	do
Novo	1	27	92.2	6.64	6.38	.13	do	53	8.4	2.21	132.6	3	48	"	2.25	.481	1.827	good	"	.0081	"	"	"	"	15	20.87	20.04	8.5	1	3	3	
do	1	28	102.0	6.16	5.92	.12	do	63	7.0	2.00	120.0	3	21		"	.529	1.773	"	"	.0075	"	"	"	"	"	19.36	18.62	7.7	1	3	4	
do	1	29	110.0	5.92	5.69	.115	do	71	6.8	2.32	139.2	2	56		2.6	.574	1.682	"	"	.0072	"	"	"	"	"	18.60	17.87	8.9	1	3	5	
do	1	30	120.0	5.69	5.46	.115	do	80	6.1	2.36	141.6	2	35	.375	2.85	.621	1.600		"	.0072	"	"	"	"	"	17.90	17.17	9.0	1	3	6	
do	1	31	114.0	5.46	5.24	.11	do	80	5.7	2.29	137.7	2	29	.46	2.75	.597	1.480	"	"	.0069	"	"	"	"	"	17.20	16.43	8.8	1	4	2	
do	1	32	127.0	5.24	5.01	.115	do	93	2.8	2.10	126.0	1	2	.43	4.0	.666	0.685	failed	failed	.0072	"	"	"	"	"	16.40	15.67	8.1	1	4	4	
Blue Chip	1	33	98.5	6.37	6.15	.11	do	59	6.9	2.19	131.4	3	9	.50	2.15	.520	1.638	good	end	.0069	"	"	"	"	13	20.03	19.31	8.4	1	3	4	
do	1	34	111.0	6.15	5.89	.13	do	69	6.6	2.41	144.9	2	44	.375	2.7	.579	1.582		"	.0081	"	"	"	"	"	19.3	18.56	9.3	1	3	5	
do	1	35	121.0	5.89	5.63	.13	do	78	6.3	2.42	145.2	2	24	.41	3.03	.628	1.510		"	.0081	"	"	"	"	"	18.56	17.78	9.3	1	3	6	
do	1	36	139.0	5.63	5.42	.105	do	94	6.2	3.10	186.0	2	0	.48	3.6	.725	1.450	limit	"	.0065	"	"	"	"	"	17.78	17.05	11.9	1	4	3	
Böhler Rapid	1	37	100.0	5.42	5.20	.11	do	70	5.7	1.60	96.0	2	33	.46	2.6	.518	1.320	good	"	.0069	"	"	"	"	20	17.05	16.34	6.1	1	3	5	
do	1	38	105.0	5.06	4.79	.13	do	80	10.9	2.56	153.9	4	18	.425	3.0	.551	2.370	"	"	.0081	"	"	"	"	"	15.87	15.06	9.8	1	3	6	
do	1	39	148.0	4.79			do	118				1	37	.475	2.75	.771	1.170	failed	failed	—	"	"	"	"	"	15.06	14.36	—	1	4	3	
Vulcan	1	40	121.0	4.54	4.34	.10	do	102	6.1	1.85	111.0	3	18	.56	2.6	.631	2.080		"	.0063	"	"	"	"	18	14.25	13.32	7.1	1	4	3	
Albion	5	41	103.0	4.34	4.12	.11	do	90	5.4	2.16	129.6	2	30	.44	2.2	.520	1.300	good	end	.0069	"	"	"	"	0	13.65	12.93	8.3	1	4	2	
do	5	42	111	4.41	4.14	.135	do	96	3.1	2.55	153.0	1	13	.42	3.3	.559	0.682	limit	"	.0084	"	"	"	"	0	13.84	13.00	9.8	1	4	3	
do	5	43	68	9.3	8.67	1/8 to 1/4	do	28	6.8	2.89	173.4	2	21	.475	3-3.75	.208	0.489	excellent	"	.0117	"	"	"	"	0	29.19	27.22	11.1	2	2	1	
McInnes	1	44	68	9.3	8.95	1/8 to 1/4	do	28	2.8					.4	3-3.25			failed	travel-2½"	.0117	"	"	"	"	16	do	28.09	—	2	2	1	
Blue Chip	1	45	68	9.3	9.00	1/8 to 1/4	do	28	7.6	1.22	73.4	6	13	"	2.5-2.8		1.293	excellent	end-7½"	.0117	"	"	"	"	13	do	28.25	4.3	2	2	1	
Vulcan	2	46	65.5	9.3	9.00	5/32	do	27	2.8	2.00	120.0	1	25	"	2.5-3	.201	0.286	cracked	in grinding	.0098	"	"	"	"	"	do	28.25	7.7	2	2	1	
Böhler Rapid	1	47	65.5	9.3	9.00	5/32	do	27	5.2	1.89	113.4	2	45	"	2.5		0.553	excellent	end-5"	.0098	"	"	"	"	20	do	28.25	7.3	2	2	1	
Novo	1	48	63.0	9.3	9.00	4/32-5/32	do	26	6.7	1.93	115.8	3	28	"	2.5	.194	0.674	"	"	.0098	"	"	"	"	15	do	28.25	7.4	2	2	1	
Blue Chip	1	49	65.5	8.93	8.38	.275	do	28	2.6	3.00	180.6	8	40		3.0	.341	3.417	"	"	.0172	"	"	"	"	13	28.1	26.31	11.5	2	2	1	
do	1	50	84.2	8.93	8.38	.275	do	36	27.2	3.88	233.1	7	0		4.25	.440	3.080	"	"	.0172	"	"	"	"	"	28.1	26.31	14.9	2	2	3	
do	1	51	96.5	8.38	7.67	.355	.0312	44	24.1	3.24	194.4	7	25	.625	3.35	.249	1.850	"	"	.0111	"	"	"	"	"	26.3	24.19	12.4	2	2	5	
do	1	52	114	8.38	7.67	.355	do	52	19.1	3.42	205.2	5	35		3.5	.294	1.640	"	"	.0111	"	"	"	"	"	do	do	13.1	2	2	6	
do	1	53	136	8.38	7.67	.355	do	62	11.5	4.60	276.6	2	30	.4	4.75	.355	0.887	"	"	.0111	"	"	"	"	"	do	do	17.7	2	3	5	
do	1	54	177	8.38	7.65	.365	.0156	81	8.8	2.98	178.8	2	57		3.25	.261	0.770	"	"	.0057	"	"	"	"	"	do	24.06	11.5	2	3	6	
do	1	55	100	7.67	7.23	.22	.0312	50	11.7	1.95	117.0	6	0	.56	2.3	.260	1.540	"	"	.0069	"	"	"	"	"	24.18	20.75	7.5	2	2	5	
do	1	56	124	7.67	7.22	.225	.0312	62	26.4	2.70	162.0	9	47	.35	2.75	.325	3.180	"	"	.0070	"	"	"	"	"	do	20.36	10.4	2	3	4	
do	1	57	136	7.22	6.92	.15	.0312	72	2.2	1.19	71.4	1	50	"	2.13	.347	.200	good	"	.0047	"	"	"	"	"	22.7	21.39	4.5	2	3	5	

Make of Tool	Tool Number	
BlueChip	1	5
"	1	5
Novo	1	6
"	1	6
"	1	6
	1	6
"	1	[illegible]
"	1	6
"	1	6
"	1	6
lbion	10	6
BlueChip	1	6
"	1	7
lbion	10	[illegible]

Tests of High Speed Tool Steel on Cast Iron 16 Elec. Driven High Speed Lathe. M.I.T. May 20, 1906

Charles E. Hayes
Fred Norwood W...

Thesis

Table VI continued

Make of Tool	Tool Number	Test Number	Cutting Speed	Initial Diam Test Piece	Final Diam Test Piece	Actual Cut	Actual Feed	R.P.M.	Wt. Cast Iron Pounds			Time	K.W.	K.W.	Area of Test Piece Machined in Square Feet		Condition of Tool	Cause of Withdrawal	Area of Section of Cut	Top Rake	Side Rake	Front Clear	Side Clear	Temper on Tool	Initial Circumference	Final Circumference	Cubic Inches Cast Iron	Test Piece	Gears	Controller	
			Ft/min	Inches	Inches	Inches	In./Rev.		Total	/min	/hr.	min sec	No Load	Under Load	Per min	Total			Sq. In.	Degrees				No.	Inches	Inches	/min.	No.	No.	No.	
Blue Chip	1	58	145	6.92	6.57	.175	.0312	80	24.7	2.14	128	11 35	.35	2.6	.374	4.330	good	end	.0054	8	30	6-10	6	13	21.78	20.7	8.2	2	3	5½	15°
"	1	59	72	6.57	—		"	100	—			1 0		—	.446	4.460	failed	failed							20.70		—		4	1½	
Novo	1	60	129		6.23	.17	"	75	8.3	2.1	126.	3 57	.38	2.18	.335	1.323	excellent	end	.0053					15		19.62	8.1				
	1	61	128	"	6.25	.16	"	74	5.5	2.2	132	2 30	"	"	.331	0.829	"	"	.005							19.32	8.5		3	5½	
	1	62	140	"	6.23	.17	"	81	6.4	2.3	139	2 48	.43	2.3	.362	1.013	"		.0053							19.62	8.9		3		
	1	63	134	6.23	5.85	.19	"	82	14.2	2.25	135	6 18	.35	2.61	.346	2.18	"		.0059						19.62	18.43	8.6		4		
	1	64	143	"	—	.19	"	88	11.3	2.81	169	4 3	"	2.87	.371	1.502			.0059							18.43	10.8		4	2	
	1	65	153	5.85	5.49	.18	"	100	6.5	2.03	122	3 12	.475	2.95	.396	1.268	"		.0056						18.45	19.13	7.8		4	3	
	1	66	190	"	"		"	124	5.7	2.41	144	2 22	"	3.6	.491	1.165	"		.0056							19.21	9.3		4	4	
	1	67	181	5.49	5.13		"	126	11.5	3.67	220	3 8	"	4.15	.468	1.405	failed	failed	.0056						17.25	16.12	14.1		4		
Albion	10	68	169	5.13	4.77		"	"	1.0	2.0	120	0 30	"	4.10	.438	0.219	failed	failed	.0056					0	16.12	15.00	7.7		4		
Blue Chip	1	69	180	"	4.74	.195	"	134	10.4	3.37	202	3 5	"	3.9	.465	1.431	good	end	.0061					13		14.57	13.0		4	5	
	1	70	207	5.49	5.13	.18	"	144	4.9	4.15	249	1 11	"	4.75	.535	0.631	good	end	.0056					13	17.25	16.12	16.0		4	6	
Albion	10	71																						0							

DISCUSSION of the TEST of

HIGH SPEED STEEL on CAST IRON.

(a) Hardening the Tools. See table IX.

A mistake was made in the directions given us for hardening "Albion" high speed steel. In order to investigate the difference in the quality of the tool when heated to different temperatures and cooled in an air blast or oil, we conducted a series of experiments with a muffle furnace and pyrometer, heating twelve small pieces of the metal to temperatures varying from 1375°F. to (2250°F.), or a good white heat. All the pieces heated below 1800°F. were soft. The quality of the tool increased gradually from 1800°F to 2000°, and at 2200°F. a good, hard, tough tool was obtained by cooling in an air blast. A muffle furnace is not desirable for hardening lathe tools because it will not give the necessary high temperature. Also, even if a high temperature is available, it is not best to use one for lathe tools unless some method is provided for heating only the nose of the tool to a white heat. If the entire tool is hardened it is very apt at heavy loads to break off under the set screw. As few heats as possible should be used on any one tool. The high heats necessary for tempering lathe tools is liable to melt the edges of the body of the tool when using a muffle furnace. When placing the tools in the air blast for hardening it was found to be advantageous to only ~~heat~~ have about one inch of the nose of the tool to be exposed to the blast, thus allowing the neck of the tool to cool down slowly and add to the toughness of the tool.

DISCUSSION of the Test of

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(b) Grinding the Tools.

It is an essential in grinding a high speed tool that care be taken not to force the tool against the wheel or allow one point to remain in contact with the same line on the wheel. Surface cracks will be produced if the tool becomes too hot while using water. These cracks tend to reduce the quality of the tool and in some cases cause it to break. Two of the "Vulcan" tools broke due to cracks made while grinding.

(c) Results.

For a certain constant feed and cut a series of runs were made on each of the six different grades of steel, the cutting speed in ft./min. being increased for each succeeding run until the tool failed. The accompanying blue print shows the performance of each tool.

Summary of Results from Blue Print.

Tool	Cut&Feed inches	Sustained speed ft./min.	#C. I. removed per min.	Area of cut sq. in.	Area of mach'd sq. ft.	Condition of tool.
McInnes	.05x.0625	134	1.39	.0031	0.7	good
Novo	.042x.0625	125	1.12	.0026	0.64	"
Blue Chip	.05x.0625	155	1.39	.0031	0.809	"
Bohler rapid	.05x.0625	170	1.59	.0031	0.883	poor
Vulcan	.055x.0625	141	1.31	.0034	.731	good
Albion	..065x.0625	111.5	1.23	.006	.566	"
McInnes	.115x.0625	126	2.57	.0072	.655	limit
Novo	.11x.0625	114	2.29	.0069	.597	good
Blue Chip	.105x.0625	139	3.10	.0065	..725	limit
Bohler Rapid	.13x.0625	105	2.56	.0081	.551	good
Albion	.135x.0625	111	2.55	.0084	.559	limit

(b) Grinding the Tools.

It is an essential in grinding a high speed tool that care be taken not to force the tool against the wheel or allow one point to remain in contact with the same line on the wheel. Surface cracks will be produced if the tool becomes too hot while using water. These cracks tend to reduce the quality of the tool and in some cases cause it to break. Two of the "Vulcan" tools broke due to cracks made while grinding.

(c) Results.

For a certain constant feed and cut a series of runs were made on each of the six different grades of steel, the cutting speed in ft./min. being increased for each succeeding run until the tool failed. The accompanying blue print shows the performance of each too

Summary of Results from Blue Print.

Tool	Cut Inches	Maintained speed ft./min.	Cu. in. removed per min.	Area of cut sq. in.	Area mach'd sq. ft.	Condition of tool.
McInnes	.05x.0625	134	[illegible]	.0031	0.7	good
Novo	[illegible]	120	[illegible]	.0029	0.64	"
Blue Chip	.05x.0625	155	[illegible]	.0031	0.806	"
Kohler rapid	.05x.0625	170	[illegible]	.0031	[illegible]	poor
Vulcan	.035x.0625	141	[illegible]	.0022	.731	good
Hinton	[illegible]	[illegible]	[illegible]	.049	.204	"
McInnes	.115x.0625	128	2.57	.0072	.655	limit
Novo	.11x.0625	114	2.26	.0066	.567	good
Blue Chip	.105x.0625	126	3.10	.0065	.725	limit
Kohler rapid	.15x.0625	105	2.56	.0091	.551	good
Hinton	.135x.0625	111	2.55	.0084	.556	limit

Tool	Cut&Feed inches	Sustained speed ft./min.	#C. I. removed per min.	Area of Cut sq. in.	Area Mach'd sq. ft.	Condition of tool
Scale cut	1/8-1/4x1/8	68	2.89	.0117	.208	excellent
Blue Chip	.355x.0312	136	4.6	.0111	.355	"
" "	.175x.0312	145	2.14	.0054	.374	good
Novo	.18x.0312	190	2.41	.0056	.491	excellent
Albion	.18x.0312	169	2.0	.0056	.438	failed
Blue Chip	.195x.0312	180	3.37	.0061	.465	good
" "	.18x.0312	207	4.15	.0056	.535	"

All tools failed on the next highest speed above that given in the above table.

The tools used in this test were worked according to the directions furnished by the makers as stated on the following pages.

COMPOSITION of HIGH SPEED TOOL STEEL.

The following may be given as the composition of a well known High Speed Steel:

Muck (Swedish)	45.0 Lbs.
Special Tool Scrap	40.0 Lbs.
Washed Metal	10.0 Lbs.
Ferro-chromium	5.0 Lbs.
Clay	4.0 Lbs.

When iron is melted the crucible is taken from the furnace and slag removed. Before replacing the following are added:

Ferro-silicon	1.5 Lbs.
Ferro-manganese	0.5 Lbs.
Metallic Tungsten	20.0 Lbs.
Flux	1.5 Lbs.

The object of the clay is to act as a decarbonizer and it proves very efficient. It removes the alloys to a large extent except chromium (probably by forming silicates) consequently these are not added until the clay is removed. The crucible is then replaced for thirty minutes.

List of the Various Steels Used in the Tests.

(1) "Vulcan" High Speed Tool Steel. Made by the Vulcan Crucible Steel Company of Aliquippa, Pa.

(2) "Bohler Rapid" Self Hardening Steel. Made by Bohler Bros. & Co., Styrian Steel Works, Vienna, Austria. Houghton & Richards, Agents, of Boston, Mass. and Chicago, Ill.

(3) "Air Novo" High Speed Steel. Herman Boker & Co.

(4) "Blue Chip" High Speed Steel. Made by the Firth-Sterling Steel Company at Pittsburgh, Pa.

(5) "Albion" High Speed Self Hardening Steel. Made by Hobson Houghton & Co., Ltd., Don Steel Wks., Sheffield, England. Chas. G. Stevens, Chicago Agents.

(6) McInnes "Extra" High Speed, Air-Hardening Steel. Made by the McInnes Steel Co., Ltd., Corry, Pa.

Hardening Number	Brand Tool	Number of Tool	No. of Heats in Forging	No. of Heats in Hardening	No. of Heats Total	Portion of Tool Heated	Tool Heated to	Temp of cooler	Method of Cooling	Fuel Used	Forge or Furnace	4/26/06 Remarks Table IX.
							F°	F°	air blast			
1	Albion	7	3	2	5	Entire Tool	1700	70	open air	Nat. Gas	Furnace	Soft
2	do	2	do	2	5	do	1750	84	do	do	do	do
3	do	7	do	2	5	do	1375	70	do	do	do	do
4	do	7(a)	do	2	5	do	[illegible]		oil	do	do	do
5	do	7(b)	do	3	6	do	do		air blast	do	do	do
6	do	7(c)	do	3	6	do	[illegible]		oil	do	do	do
7	do	7(d)	do	3	6	do	1525		oil	do	do	do
8	do	7(e)	do	3	6	do	1700		open air	do	do	do
9	do	7(f)	do	3	6	do	1800		do	do	do	Tool fairly hard
10	do	7(g)	do	3	6	do	1840		do	do	do	do
11	do	7(h)	do	3	6	do	do		do	do	do	do
12	do	7(i)	do	4	7	do	1520		do	do	do	do Heat Albion to a White heat to get good results
13	BlueChip	1	2	1	3	Nose	Melt W.H	80	air blast	Coke	Forge	Tool hard.
14	do	2	2	1	3	do	do	do	do	do	do	do
15	Novo	1	1	1	2	do	Melt W.H	70	Kerosene and air blast	do	do	Point melted.
16	McInnes	1	1	1	2	do	Melt W.H	do	air blast	do	do	do
17	Novo	2	1	1	2	do	do	75	do	do	do	do
18	Vulcan	1	1	1	2	do	Weld W.H	do	oil	do	do	do
19	do	2	1	1	2	do	do	do	do	do	do	do
20	Bohler Rapid	1	1	1	2	do	Good W.H	do	air blast	do	do	a good incandescent white heat. Point not melted
21	do	2	1	1	2	do	do	do	do	do	do	do
22												

Instructions for Forging and Hardening Grades of HIGH SPEED TOOL STEELS.

These instructions were furnished by the makers of the steels. For lathe, planer, and similar tools.

(1) Instructions for working "Air Novo" steel.

The bar should not be broken cold: it should be cut off hot.

FORGING.- The heating should be done slowly in a well burned through, hollow, coal fire or in a charcoal fire and care taken that the heat has thoroughly "soaked" through the end which is to be forged and the forging should be done at a high lemon color heat. The heat color should be like the glowing fibre of an incandescent lamp and the steel should be so hot that it forges on an anvil with a dull sound and without a metallic ring, giving readily under the forging hammer. This lemon color heat is absolutely necessary in forging. Time may be saved by grinding the tool on a dry emery wheel while the forged tool is still red hot from the forge. After forging, permit the tool to grow cold by itself on the floor.

HARDENING.- Take the forged tool which, as stated above, should be permitted to grow cold gradually, and bring the forged end or nose into a well burned through, coal or charcoal fire (not a gas furnace because a gas furnace will not make the steel hot enough) slowly to a white heat. This extreme white heat should confine itself to about 1/2 to 3/4 of an inch from the nose of the tool and should be so hot that the steel begins to fuse and blister. This high heat is absolutely necessary. Do not allow the air blast in the forge to play on the point of the tool.

Instructions for Forging and Hardening Grades

of HIGH SPEED TOOL STEELS.

These instructions were furnished by the makers of the steels. For lathe, planer, and similar tools.

(1) Instructions for working "Air Novo" steel.

The bar should not be broken cold: it should be cut off hot.

FORGING. - The heating should be done slowly in a well burned through, hollow, coal fire or in a charcoal fire and care taken that the heat has thoroughly "soaked" through the end which is to be forged and the forging should be done at a high lemon color heat. The heat color should be like the glowing fibre of an incandescent lamp and the steel should be so hot that it forges on an anvil with a dull sound and without a metallic ring, giving readily under the forging hammer. This lemon color heat is absolutely necessary in forging. Time may be saved by grinding the tool on a dry emery wheel while the forged tool is still red hot from the forge. After forging permit the tool to grow cold by itself on the floor.

HARDENING. - Take the forged tool which, as stated above, should be permitted to grow cold gradually, and bring the forged end or nose into a well burned through, coal or charcoal fire (not a gas furnace because a gas furnace will not make the steel hot enough) slowly to a white heat. This extreme white heat should confine itself to about 1/2 to 3/4 of an inch from the nose of the tool and should be so hot that the steel begins to fuse and blister. This high heat is absolutely necessary. Do not allow the air blast in the forge to play on the point of the tool.

At this white fusing heat, quickly draw the tool from the fire and put the white hot part in contact with the strongest and coldest air blast which is available, letting the tool get cool so that it may be picked up with the bare hand. Compressed air will give the best results, however, good results are secured with as low as two pounds of air. Under all conditions avoid bringing the tool into contact with water while hot.

Equally good results are obtained by hardening the white hot nose of the tool in free running oil (that is, so that cool oil at about 80°F. or less comes continually in contact with the hot tool) Kerosene, fish oil, or lard oil will give the best results. The tool should be permitted to grow comfortably cold in the oil, all the time keeping cold oil in contact with the tool and then the cooling off process should be continued in a cold blast. When the tool is thrust into the oil it should be given a motion in a direction parallel to the sides of the stock of the tool. The white hot nose of the tool should touch the oil first. After the tool comes out of the oil the nose must show signs of having been fused a trifle and must have a greyish white appearance.

GRINDING.- Grind on a wet emery wheel but with a plentiful supply of water and not too forcibly as surface cracks might be created. These cracks might cause the tool to break off.

A dry emery wheel could be used taking care that the steel does not become discolored. See that grinding wheel is not glazed.

(2) Instructions for working "Blue Chip" high speed steel.

(a) For lathe, planer, and similar roughing tools.

At this white fusing heat, quickly draw the tool from the fire and put the white hot part in contact with the strongest and coldest air blast which is available, letting the tool get cool so that it may be picked up with the bare hand. Compressed air will give the best results, however, good results are secured with as low as two pounds of air. Under all conditions avoid bringing the tool into contact with water while hot.

Equally good results are obtained by hardening the white hot nose of the tool in free running oil (that is so that cool oil at about 60°F. or less comes continually in contact with the hot tool) Kerosene, fish oil, or lard oil will give the best results. The tool should be permitted to grow comfortably cold in the oil, all the time keeping cold oil in contact with the tool and then the cooling off process should be continued in a cold blast. When the tool is thrust into the oil it should be given a motion in a direction parallel to the sides of the stock of the tool. The white hot nose of the tool should touch the oil first. After the tool comes out of the oil the nose must show signs of having been fused a trifle and must have a greyish white appearance.

GRINDING.- Grind on a wet emery wheel but with a plentiful supply of water and not too forcibly as surface cracks might be create. These cracks might cause the tool to break off.

A dry emery wheel could be used taking care that the steel does not become discolored. See that grinding wheel is not glazed.

(2) Instructions for working "Blue Chip" high speed steel.

(a) For lathe, planer, and similar roughing tools.

FIRE.- For this class of tools a good fire is one made of hard foundry coke, broken into small pieces, in an ordinary blacksmith forge with a few bricks laid over the top to form a hollow fire. The fire must be well burned through, and solid, so that the blast does not touch the tool. The bricks should be thoroughly heated before the tools are hardened. Hard anthracite coal may be used very successfully in place of hard coke and will give a higher heat.

FORGING.- Heat the nose of the tool slowly and uniformly to a good forging heat. Do not hammer the tool after it has cooled below a bright red heat. Avoid as much as possible heating the body of the tool, so that the natural toughness in the neck of the tool is retained. Time can be saved by grinding the tool while red hot from the forge.

HARDENING.- Heat the point of the tool to an extreme white heat until the flux runs. This heat should be the highest possible short of the melting point. Care should be taken to confine the heat to the end of the tool so that the tool will retain its natural toughness in the neck where it is held in the tool post.

Draw the tool quickly from the fire and cool in a good air blast, or in oil such as fish or cotten-seed. 5 ?

Grind the tool on a dry emery wheel.

For finishing tools harden according to the directions for hardening milling cutters. (See next page).

FIRE. - For this class of tools a good fire is one made of hard foundry coke, broken into small pieces, in an ordinary blacksmith forge with a few bricks laid over the top to form a hollow fire. The fire must be well burned through, and solid, so that the blast does not touch the tool. The bricks should thoroughly heated before the tools are hardened. Hard anthracite coal may be used very successfully in place of hard coke and will give a higher heat.

FORGING. - Heat the nose of the tool slowly and uniformly to a good forging heat. Do not hammer the tool after it has cooled below a bright red heat. Avoid as much as possible heating the body of the tool, so that the natural toughness in the neck of the tool is retained. Time can be saved by grinding the tool while red hot from the forge.

HARDENING. - Heat the point of the tool to an extreme white heat until the flux runs. This heat should be the highest possible short of the melting point. Care should be taken to confine the heat to the end of the tool so that the tool will retain its natural toughness in the neck where it is held in the tool post.

Draw the tool quickly from the fire and cool in a good air blast, or in oil such as fish or cotton-seed.

Grind the tool on a dry emery wheel.

For finishing tools harden according to the directions for hardening milling cutters (See next page).

(b) For Milling Cutters, Drills, Taps, Reamers, Formed Cutters, and similar tools.

FIRE.- Gas furnaces designed for high heats are now made and do very satisfactory work in hardening this class of tools. There are furnaces on the market made especially for this purpose. Where a furnace is not convenient these tools can be hardened in a forge fire as described for hardening lathe and similar tools but care must be taken to keep the tool away from contact with the fuel.

HARDENING.- Tools should be heated to a white heat just below the blistering point. The heat should be the highest possible in view of the importance of preserving the cutting edges. The higher the heat the better the tool. In cooling, quench in oil immediately when taken from the fire as described for lathe tools.

For this class of tools and for lathe finishing tools draw the temper to a dark straw color of about 500°F.

(3) Instructions for working "Vulcan" high speed steel.

Heat the tools to an absolute <u>white</u> or <u>welding</u> heat and then cool in oil (not kerosene).

With tools of intricate shape or having fine or sharp edges, heat as near a <u>white</u> heat as possible and cool as above.

This steel cannot be hurt by burning.

(b) For Milling Cutters, Drills, Taps, Reamers, Formed Cutters, and similar tools.

FIRE.- Gas furnaces designed for high heats are now made and do very satisfactory work in hardening this class of tools. There are furnaces on the market made especially for this purpose. Where a furnace is not convenient these tools can be hardened in a forge fire as described for hardening lathe and similar tools but care must be taken to keep the tool away from contact with the fuel.

HARDENING.- Tools should be heated to a white heat just below the blistering point. The heat should be the highest possible in view of the importance of preserving the cutting edges. The higher the heat the better the tool. In cooling, quench in oil immediately when taken from the fire as described for lathe tools.

For this class of tools and for lathe finishing tools draw the temper to a dark straw color of about 500°F.

(3) Instructions for working "Vulcan" high speed steel.

Heat the tools to an absolute <u>white</u> or <u>welding</u> heat and then cool in oil (not kerosene).

With tools of intricate shape or having fine or sharp edges, heat as near a <u>white</u> heat as possible and cool as above.

This steel cannot be hurt by burning.

(4) Instructions for working McInnes "EXTRA" High Speed, Air-Hardening Steel.

FORGING.- Heat the steel (away from the blast) slowly, thoroughly, and evenly at the ordinary tool steel forging heat taking care to heat the steel uniformly to the center: then shape the tool. Avoid hammering the steel when it has cooled below a dull red.

HARDENING.- After the tool is forged to the desired shape reheat the cutting end until it sweats or just before it runs: then cool off in an air blast or dip in fish oil.

(5) Instructions for working "ALBION" High Speed Self-Hardening Steel.

FORGING.- Heat gradually but thoroughly to a cherry red, in the same manner as tempering Tool Steel.

HARDENING.- Reheat to a white heat and cool in oil.

(6) Instructions for working "BOHLER RAPID" Styrian High Speed Steel.

FORGING.- Heat to a bright yellow color. Do not allow the heat to run as low as a cherry red while forging. After forging allow the tool to cool slowly before hardening.

HARDENING.- For lathe, planer, and boring tools heat to a white heat but not to a scaling or melting point. Cool in air or in a cold blast. For milling cutters, taps, reamers, and twist drills heat as above and cool in fish oil. The temper of the latter class of tools should be drawn in tempering oil.

(4) Instructions for working the [illegible] "[illegible]" High Speed, Air-Hardening steel.

FORGING. - Heat the steel (away from the glass) slowly, thoroughly, and evenly at the ordinary tool steel forging heat taking care to heat the steel uniformly to the center; then shape the tool. Avoid hammering the steel when it has cooled below a dull red.

HARDENING. - After the tool is forged to the desired shape reheat the cutting end until it sweats or just before it runs; then cool off in an air blast or dip in fish oil.

(5) Instructions for working "[illegible]" High Speed Self-Hardening Steel.

FORGING. - Heat gradually but thoroughly to a cherry red, in the same manner as tempering Tool Steel.

HARDENING. - Reheat to a white heat and cool in oil.

(6) Instructions for working "[illegible]" Styrian High Speed Steel.

FORGING. - Heat to a bright yellow color. Do not allow the heat to run as low as a cherry red while forging. After forging allow the tool to cool slowly before hardening.

HARDENING. - For lathe, planer, and boring tools heat to a white heat but not to a scaling or melting point. Cool in air or in a cold blast. For milling cutters, taps, reamers, and twist drill heat as above and cool in fish oil. The temper of the latter class of tools should be drawn in tempering oil.

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